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of

Civil Engineers

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SOCIETY AFFAIRS

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AMERICAN SOCIETY OF CIVIL ENGINEERS

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SOCIETY AFFAIRS

SPRING MEETING, WASHINGTON, D. C., APRIL 25-27, 1928

The selection of Washington, D. C., for the Spring Meeting appears to be ideal, from the standpoint of the many places of interest to visitors that the City furnishes, as well as the excellent railroad facilities that are available to a large proportion of the membership.

The technical program will open on Wednesday morning, April 25, with a number of addresses on the work of the Government Departments, particularly the Bureau of Standards, and their relations to engineering. In the afternoon, a visit will be made to the Bureau where members will have an opportunity to obtain first-hand information on its vast activities and its importance in the scientific and engineering world. A number of large-scale experiments of particular interest to engineers will be on view.

On Thursday, April 26, the entire day will be given over to sessions of the Technical Divisions. The Construction, City Planning, Surveying and Mapping, Structural, and Sanitary Engineering Divisions have prepared programs covering their respective fields. In addition, there will be an exhibit showing instruments, maps, and map-work of all the Federal Departments engaged in making surveys and maps, the following organizations contributing to this display: Department of Commerce; Department of the Interior; War Department; Navy Department; Agricultural Department; Post Office Department, and possibly others.

For Friday, April 27, an all-day excursion has been arranged; this, it is felt, will be of great interest to the ladies as well as to members. The objective of the trip will be Camp Humphreys, Va., where all the equipment of engineer troops will be inspected and its use demonstrated. On arrival of the party at Camp Humphreys, there will be a parade of a war combat company of engineers with all transportation, followed by a company in attack, with blank ammunition.

Luncheon will be served in the Service Club, following which the party will go to the Pontoon School where all types of pontoon equipage and means of transportation will be displayed. There will be demonstrations of various kinds of bridge construction, including races in pontoon bridge building.

Another part of the exhibit will be the mapping apparatus of the Twenty-Ninth Engineers, showing the complete map reproduction train in operation, as well as the divisional water supply equipment. Following this inspection, there will be a polo game after which the party will return to Washington.

The route of the trip from Washington will be by way of the Lincoln Memorial, the Lee House at Arlington, and Mount Vernon. At Mount Vernon, there will be about an hour for the inspection of the Washington Home and Buildings. Buses will be arranged for the return to Washington of those who wish to spend considerable time at Mount Vernon.

In addition to the technical features outlined, it is expected that a very attractive program of entertainment will be arranged for the ladies, including visits to points of scenic and historic interest in the vicinity of the Capitol. These and the many other details of this

splendid meeting will be covered fully by the official program shortly to be issued.

In making such comprehensive plans to enjoy the technical program and the multitude of attractions of the Capitol just at the height of Spring, the Local Committee has aimed to appeal to every engineer. Members and their families can arrange to attend with the utmost confidence and expectation.

THE LOCAL SECTION AS A GOOD SAMARITAN

What it means to claim the privilege of membership in the Society when a person is far from home is well illustrated in the recent experience in New Orleans of a Philadelphia member and his wife. They were touring through the city when he was stricken with a sudden and fatal illness.

Previously, however, he had made himself known to a local engineer because of his membership in the Society. The news of the sad circumstances was rather indefinite so that considerable difficulty ensued in trying to locate the widow in a strange city.

Meantime the Local Section became active and made its influence immediately felt; the President went through the list of undertakers and rang up each in turn until on the eighth try he found the full information and was able to get the complete details.

Then followed a thoughtful and extensive personal assistance. Telegrams were sent, flowers obtained, and all arrangements made for the proper funeral services. All this, remember, was on behalf of an utter stranger who had been in New Orleans less than two days.

One can speculate as to how a lone woman without acquaintances could have otherwise succeeded in getting through such an ordeal. No end of credit is due F. A. Muth, President of the Louisiana Section, Professor Derickson, and their families, for the extreme thoughtfulness in this trying situation.

Every member will say "aye" to this tribute. He knows that the same help is his in the case of need and he must know too that the same privilege may some day come within his grasp. The Society does not stress the social value of its membership, but that value is nevertheless present and vital. In many cases, as in this, the small blue badge has a mystic effect, beyond the power of members to assess in value.

Perhaps a similar outcome would have resulted had neither the membership in the Local Section or in the Society been involved. Certainly, sympathy and help are not merely a matter of professional brotherhood. Yet the fact remains that because the man was a Member, and because a Local Section of the Society was at hand, with members who were "on their toes" to their ideals and opportunities, the thing was accomplished. All credit to them.

EARLY WOODEN WATER PIPE

The early history of American waterworks has various references to wooden pipe. Such crude engineering material has been found, for example, in excavating for New York subways. The most recent example of this sort, however, comes from Bethlehem, Pa. This specimen, an interesting survival of the earliest American water-works, has been donated to the Engineering Societies Library by Robert L. Fox, Assoc. M. Am. Soc. C. E., City Engineer, Bethlehem, Pa.

This pipe was laid in 1754, and formed part of a wooden force main extending from the spring, then the water supply of the town, to a wooden reservoir, about 400 ft. distant, and possibly 70 ft. higher. The pipe was made of bored hemlock logs, charred inside, and in sections of 8 to 12 ft. long. One end was simply pointed; that was the spigot. The bell was just an enlarged section, surrounded by wrought-iron hoop about 10 in. in diameter.

The water-works was built by Hans Christopher Christiansen, a Danish millwright, who became a member of the Moravian settlement at Bethlehem in 1751. He is the first water-supply engineer of record in this country, and this particular pipe formed part of the first American force main.

The Library is deeply indebted to Mr. Fox for this fine specimen. It shows the bell end of a pipe, with the original hoop in position, and is in a good state of preservation.

ENGINEERING TEACHERS' SUMMER SCHOOL

Second Year's Sessions Will Study Physics and Electrical Engineering

So great was the success of the Summer School for Engineering Teachers held last year under the auspices of the Society for the Promotion of Engineering Education, that the project is being

continued for the approaching summer. It will be remembered that a year ago the question of teaching mechanics was covered intensively, to the great advantage of about 80 young engineering teachers.

For this year's continuation, the subjects of physics and electrical engineering have been chosen. In this effort the main concern is with the methods of teaching rather than the actual content of courses. As a matter of convenience and of appeal to the largest number of teachers, the sessions will be held in two places at some distance apart. The session on physics will be held at the Massachusetts Institute of Technology, Cambridge, Mass., and that on electrical engineering in Pittsburgh, Pa., under the joint auspices of the University of Pittsburgh and the Westinghouse Electric and Manufacturing Company. Both sessions will be under the general charge, for the Society for the Promotion of Engineering Education, of H. P. Hammond, M. Am. Soc. C. E.

Each session will be of three weeks' duration, beginning shortly after July 4. Judging by the experience of a year ago, the attendance will present widespread interest. The only expense other than for transportation and living, will be a nominal fee of $10 for registration. Full information may be had by addressing Professor H. P. Hammond, Associate Director, Investigation of Engineering Education, 33 West 39th Street, New York, N. Y.

AN ENGINEERING EXPERIENCE MEETING

At one of its recent meetings, the Lehigh Valley Section of the Society made an innovation in its program which proved a decided success. A number of speakers, all local members, were pressed into service, each giving remarks of a personal nature connected with his work, his experience, his ideas of Society conduct, his recollections of former eminent engineers, or any other topic that appealed to him.

Of course the result was successful because it received the co-operation of all the Section members. Among the speakers were numbered a College President, Dr. C. R. Richards; a teacher of engineers, F. O. Dufour (also a Director of the Society); and other members prominent in local engineering work, including Messrs. George H. Blakeley, F. C. Schall, and B. C. Collier.

The Lehigh Valley Section recommends a similar procedure to other groups of members. It has the advantage of simplicity, ease of arrangement, and social as well as engineering value.

A GREAT STOREHOUSE OF ENGINEERING INFORMATION*

Distant Users of the Engineering Societies Library

Frequent among the requests that come by mail and telephone to the Engineering Societies Library, are those relating to priority in connection with patents. Perhaps a metallurgist in the West writes to ask about the foreign literature on improvements in the refining of zinc, in order to compare his own inventions with those in other countries; or a chemical company in New Jersey telephones for a bibliography of lawsuits over a delicate question of infringement; or an engineer who anticipates trouble in proving to the Patent Office that he has invented a new device wants photoprints of early pictures of similar devices.

The path of an inventor is so thorny, and the question of priority frequently such a chaotic one, that the Library Staff hopes to develop a specialized technique for the assistance of those who wish to protect their rights to new devices and processes. More engineers than is commonly supposed come into contact at one time or another with America's confused Patent Law. The natural place for them to turn for information, at least in the early stages of their problem, is the Engineering Societies Library which is, in fact, becoming a sort of clearing house for technical information.

To indicate the widening scope of the Library as a center of technical inquiry by distant users, it is interesting to note that requests for information during 1926 came to the Staff from forty-six States and thirty foreign countries. There is an implied compliment to American engineering practice when inquiries for information come from such distant countries as New Zealand, South Africa, and Denmark.

* This is the sixth of a series for the information of the membership of the work of Engineering Societies Library. The first five items were published in November and December, 1927, and in January, February and March, 1928, *Proceedings*.

An interesting request of a distant user was one from the Japanese Government for a description of New York's subway system. This was to aid in introducing subways into Japanese cities. At about the same time a dredging company in Hawaii wrote asking for photoprints of an article explaining the use of compressed air as a protection against high waves along the sea coast. This company was being hindered from work by the waves and had heard of compressed-air bubbles as a pacifier. A little later there came a cablegram from a sugar company in Cuba asking about a recent article on safe operating temperatures of turbo-alternators.

Not all calls, however, are from such a great distance. A recent telephone message from a chemist asked for the published composition of the limestone in certain mountains near Albany, N. Y. A city engineer in Pennsylvania rang up for information about the use of arcades in New York's streets. This was a consequence of innovations being tried for the relief of congestion of traffic. Another request of the same nature was for pictures of trolley cars used in New York Streets. "Can you refer me to information on early paper-making by the Chinese?" was one telephone message. Another asked for data on the cast iron used in the city fountain at Versailles, France, about 1600. And so it goes. The technical curiosity of American engineers is insatiable.

APPOINTMENTS OF SOCIETY REPRESENTATIVES

Among the various recent appointees to represent the Society are the following:

Joint Committee of Founder Societies on The Washington Celebration in 1932: Charles S. Churchill, M. Am. Soc. C. E.

Society Representative at World Engineering Congress, Tokyo, Japan, October, 1929: George W. Fuller, M. Am. Soc. C. E.

Society Representative for Expression of Appreciation to New York State Bridge and Tunnel Commission and the New Jersey Interstate Bridge and Tunnel Commission: W. T. Chevalier, M. Am. Soc. C. E.

Society Representative on the Advisory Council of the Board of Surveys and Maps of the Federal Government: Lenox R. Lohr, M. Am. Soc. C. E.

TRAFFIC CONTEST

The United States is awake to the immensity of the traffic problem. Evidences of this are noticeable on every hand. One of the most recent is in connection with a contest involving prizes of $10 000 now being conducted by the magazine, *Nation's Traffic*.

The particular prizes vary in amount for the different subjects. For example, the first award of $2 500 is for the best "Uniform Traffic Ordinance." Another is for traffic regulation by signals. One is on parking problems, and so on through the list of fifteen awards, the last being for $100.

As in all such problems, the engineer is a potent influence. Hence, it is only reasonable that he should be able best to solve the difficulty, and—what is equally important—obtain the recognition and resulting money award. As this contest closes April 30, any members interested should write without delay to the *Nation's Traffic*, Title Guarantee Building, St. Louis, Mo.

APPRECIATION OF ENGINEERING FOUNDATION

Actions speak louder than words. No matter what may be the general opinion regarding any movement it is the translation of thoughts into actual practice that counts.

A specific instance of this occurred recently in connection with Engineering Foundation. For many years this agency of the Founder Societies has been doing excellent work in the promotion of research, as instanced by the Arch Dam investigation which is so widely and favorably known to all civil engineers.

The present tangible appreciation came from the Central Hudson Gas and Electric Corporation of Poughkeepsie, N. Y., in the very substantial form of $10 000 in securities. The particular source of this fund is of interest. As mentioned in the letter of transmittal by T. R. Beal, President of the Corporation,

"This amount was in fact earned by our employees by their more efficient operation of the physical properties under their care. It represents $10 000 of return premiums paid during the past year on accident insurance, as the result of the Company's excellent record in preceding years, so that we take greater satisfaction in making this gift as it is related, in some degree at least, to the higher standards of engineering

and operating practice to which the work of the Foundation pertains. Also, it gives us pleasure to testify to our appreciation of the men who made the Foundation possible and of the work that is being accomplished for the benefit of our Industry."

This fine tribute and substantial remembrance is an example for all industries which have to deal with engineering programs, especially in connection with the modern developments in science. Engineering Foundation has earned the widespread good-will of American business. It is pleasant to think that the results of this as in the present instance are to be re-invested in furthering this cause.

ENGINEERS EVALUATE EDUCATIONAL POLICY

Various engineers, to the number of almost 2 000, and including 500 or more civil engineers, mostly members of the Society, have recently subscribed to a questionnaire involving engineering education. This was part of the work fostered by the Society for the Promotion of Engineering Education, through its Board of Investigation and Co-ordination. In this work, the Society has cooperated for several years, both in personnel and in funds.

This latest study has concerned the attitude of engineers toward under-graduate education. It is with the views of the practicing engineer that the present summary is mostly concerned.

The scope of the investigation was broad. It covered the fundamental elements of engineering courses, the degree of differentiation needed, the amount of specialization, and the extent of training in several particular courses or subjects required. In addition to this rather specific content, a second group of inquiries dealt more with the general questions of policy rather than of practice, and included the relation of the National Engineering Societies to the larger matter of engineering education.

Ideal Content of Courses

One of the first questions was as to the subjects to be included in all engineering curricula; mathematics, physics, chemistry, drawing, and English were specifically excluded from this question. Of course, a variety of answers were given, of which the leading ones in order of importance were Mechanics and Mechanics of Materials, both of which received almost 90% of approval. Then followed in order Elements of Electrical Engineering, Economics, Hydraulics, Surveying, and Thermodynamics (about 60%), followed by a number of others, with rapidly decreasing approval. Among the civil engineering replies to this question, the general trend was in conformity with the average, except that a special emphasis on Surveying (75%) and a corresponding disparagement of Thermodynamics (40%) was evident.

Again, on the question of specialization within a given branch, the opinion was strongly in favor of teaching general principles and methods, rather than particular subjects for special fields of work. The average ratio in favor of the principles as opposed to the specialized field was about 12 to 1; whereas the replies from the civil engineers were in the ratio of 17 to 1.

To a variety of questions the answers of the civil engineer will be of interest. He believes that a moderate to a large amount of emphasis should be given to economics; that he is nowhere nearly as well prepared to deal with economic problems as with the technical matters; that modern languages are little justified by their cultural value in proportion to the time expended; that of the modern languages, French and German are most useful (in almost equal value), with Spanish a rather poor third, only half as much as either of the others.

For Civil Engineers Only

Printed specific questions were addressed only to civil engineers, for example, as to what subjects warrant inclusion in all civil engineering courses. Four such subjects received between 80 and 90% of these votes, namely, Plane Surveying, Reinforced Concrete, Framed Structures, and Foundations. The next group, favored by 50 to 60%, included (in order of preference), Public Water Supply, Sewerage and Sewage Disposal, Highway Engineering, Building Construction, and Railroad Engineering. Following this were eleven items of lesser relative importance.

Still another query related to the special divisions of Civil Engineering that warranted distinct and complete curricula. Among the specific answers to this inquiry the greatest number (75%) favored structural study; next came the sanitary and hydraulic branches (66% each); then railroad (60%), highway (47%), architectural (45%), municipal (39%), and others.

All these data are but the merest skimming of the interesting report which has been issued as *Bulletin No. 13* of the Investigation of Engineering Education. Beyond the tabulation of replies in graphical form, a summary and comment on each of the basic questions is included. In addition, many excerpts from the replies of individual engineers are included in reference to the more important specific questions. All in all, this 60-page booklet contains a great deal of meat in which all engineers who are awake to the needs of technical education, will take a lively interest. Copies may be obtained by addressing the Lancaster Press, Inc., Lancaster, Pa.; the cost is 30 cents.

A MID-WINTER ENGINEERING TOUR

Members of the Illinois Section in conjunction with the Western Society of Engineers recently enjoyed a most satisfying five-day trip to the Gulf of Mexico. The tour embraced Gulfport, Miss., various cities on the Gulf adjoining New Orleans, where two days were spent, and on the return trip, Vicksburg, Miss., where a full day was occupied in interesting sights.

In all the party numbered almost fifty, comfortably filling two special Pullmans. At each place the time was well distributed by efficient planning so that the arrangements went through without a hitch. Every type of engineering work came in for proper attention. The social side was not forgotten, and the Southern engineers went out of their way to provide luncheons, dinners, sightseeing tours, inspections, and various other means of helpful entertainment.

So successful was the entire venture considered that others are already being talked over. The Illinois Section has a member in constant connection with the Western Society of Engineers for joint arrangement of similar or less pretentious excursions. The news of this engineering trip should be an inspiration and encouragement to other Sections that may have similar plans in mind.

RESEARCH FELLOWS AT UNIVERSITY OF WISCONSIN

Inquiries are invited by the University of Wisconsin regarding the filling of two research fellowships in engineering. The appointments will be for a period of two years, subject to satisfactory service, at salaries of $900 and $1 100 for the respective years. About half the time will be devoted to research in the College of Engineering, with additional opportunities to secure a Master's Degree within these total periods, which will cover the usual academic years, including vacations.

The requirements of candidates are that they must be graduates of recognized engineering schools, preferably with subsequent experience in teaching or studying. Because the appointment is to be made on April 30, applications must be in hand by April 15. Information and application blanks can be obtained from Dean F. E. Turneaure, M. Am. Soc. C. E., College of Engineering, Madison, Wis.

GENERAL CONTRACT SYSTEM RECEIVES ENGINEERS' APPROVAL

The large question of forms of contract was the subject of prolonged discussion at the regular Society Meeting on March 7, 1928. The basis for the meeting was the paper "General Contract System Versus Segregated Contracts", which was presented by the author, Ward P. Christie, Assoc. M. Am. Soc. C. E.

Mr. Christie's attitude was that the general contractor is best able to handle and co-ordinate the various factors entering into large construction work. In his support of the general contract system, he was ably seconded by a number of members who entered heartily into the ensuing discussion. President Bush called on representatives of construction, engineering and contracting interests. Although different phases of the question were broached by these many speakers, the general trend of thought was distinctly uniform. While some of the grievances of contracting were aired quite candidly, the contractor himself received a remarkably clean bill of health by representatives of both the engineering and construction industries.

Co-operating in this discussion were the following members: Messrs. W. A. Starrett, W. J. Barney, Lazarus White, L. S. Stiles, E. W. Bush, G. R. Tuska, T. Kennard Thomson, Robert Ridgway, R. E. Bakenhus, H. G. Moulton, and H. M. Dougherty. Mr. Christie and each of these discussors had individual and worth-while ideas, and they were presented with a freshness that gave a pleasing spontaneity to the meeting. The attendance was about 100.

FEDERAL HEALTH CO-ORDINATION

A bill which includes provisions for an improved status for the sanitary engineers attached to the U. S. Public Health Service, was passed by the House of Representatives on March 7, 1928. This is known as the Parker Bill, H. R. 11026, "A Bill to Provide for the Co-Ordination of the Public Health Activities of the Government, and for Other Purposes". A Committee of the Society, consisting of Messrs. George W. Fuller, Chairman, Morris Knowles, and William L. Stevenson, has been active in behalf of such legislation since the Board of Direction authorized a special committee for this purpose in 1924, and has co-operated with a similar committee of the American Public Health Association.

The particular activities of the Society and of the Committee have consisted of communicating with the Local Sections and individual members of the Society, recommending endorsement of this legislation to members of the House of Representatives from their respective localities. The Society had been represented previously by Mr. Fuller at the hearing before the Interstate and Foreign Commerce Committee of the House of Representatives, which hearing resulted in an entirely favorable report and subsequent enactment.

In addition to providing an improved status for the sanitary engineers and other scientific and technical personnel equal to that of the medical personnel in the U. S. Public Health Service, the Parker Bill provides for co-ordination and increased efficiency in Federal health work. Salient features include (1) the co-ordination of Federal health work through the authorization of detailing of Public Health Service personnel to other Government departments to co-operate in the conduct of their health activities; (2) the authorization of additional divisions in the Hygienic Laboratory; (3) the making available of the facilities of the Hygienic Laboratory to health officers and other scientists and permitting the assignment of Public Health Service personnel to educational and scientific institutions for special studies; and (4) the creation of a National Advisory Health Council representing various branches of the public health profession.

This legislation was also introduced in the United States Senate on February 23, 1928, by Senator Wesley L. Jones, of Washington, Chairman of the Committee on Commerce. The identical bill bearing the Senate number of S. 3356 has been referred to the Senate Committee on Commerce. After another hearing, if favorably reported to the Senate by the Committee, this bill will come up for a vote by the entire Senate. It is probable that the Society will be represented before the Senate Committee on Commerce at this hearing.

THE LOCAL SECTION AND ITS NEIGHBORING STUDENT CHAPTER

The Northeastern Local Section of the Society has given serious consideration to its responsibility as regards engineering colleges and Student Chapters in its neighborhood. It appointed a committee to study this matter, composed of the following members: Messrs. Charles W. Sherman, Dwight Porter, and Lewis E. Moore.

While much of the recent report of this Committee deals with the local situation, the conceptions expressed regarding the function of the Committee are applicable to all Local Sections, and are especially apropos at this time when both colleges and Local Sections are attempting to make a fitting close to their active year's work before the summer season.

As these members of the Northeastern Section understand the situation, their duties might include the following maters:

1.—Assisting existing Student Chapters by maintaining contact with their faculty sponsors, assisting in obtaining speakers when desired, and in other ways makings it apparent to the Chapters that the Society and the Section are interested in their welfare.

2.—Assisting in forming new Student Chapters.

3.—Bringing to the attention of engineering students about to graduate, whether or not they are members of Student Chapters, the desirability of taking out Junior Membership in the Society.

4.—Considering any other matters in which the Section may be of assistance to engineering students.

Their category might conveniently stand as a sort of platform on which all Local Sections could build their efforts. Doubtless, the Student Chapters themselves will feel a corresponding duty toward the Local Section which takes such a fatherly interest in them.

WORLD ENGINEERING CONGRESS
Tokyo, Japan, October, 1929

One of the matters of outstanding importance in engineering circles is the proposed World Congress being planned for October, 1929, to be held in Tokyo, Japan. This event is only a year and a half away. Because of its importance and the elaborateness of the necessary provisions plans are already being considered in some detail.

The matter was broached officially to American engineers on the occasion of a visit of Baron Shiba last fall. Baron Shiba was entertained in New York and made a brief announcement to representatives of all the Engineering Societies. He outlined the plans already under way, the advantages that would accrue from such a wide representation of engineers, and the hospitable preparation of the Japanese Government and people.

It is understood that the formal invitation will be extended to the various Societies through the State Department at Washington. Meanwhile, the matter is being actively considered by all organizations concerned, including the Society, having received the approval of the Board of Direction at its January meeting. As a result George W. Fuller, Vice-President, has been appointed to serve for the Society on a Joint Committee of Participation by American Societies.

VISIBLE RECORD OF PAST OFFICERS

A valuable service to the Society is being performed by H. W. Dennis, Director, in collecting a number of reels of "movies", dealing with Society personalities. Many of the officers, both present and former, are included in this notable set of pictures. The mannerisms, characteristic poses, and geniality are all here recorded for future generations.

What this may mean in terms of value to the Society records is beyond conjecture. One who has viewed such a set of pictures can conceive of no better way of recording details that are beyond description. One of the most valuable benefits of Society work is admitted to be the social contacts and friendships developed. In years to come, members will view these motion pictures showing old friends and respected associates with increasing interest and value. Director Dennis deserves a deal of credit for his persistence in collecting these valuable and fascinating records.

Local Sections*

Baltimore.—March 2, 1928. A dinner meeting was held at the Engineers Club, at which Major Dan I. Sultan, Corps of Engineers, U. S. Army, gave an address outlining the plan proposed by the Corps of Engineers for Mississippi River flood control. Major Sultan stated in an interesting and lucid manner the various major difficulties to be overcome. A general discussion followed. Resolutions were adopted endorsing the "Bill to Provide for the Re-organization of the Public Health Activities of the Government and for Other Purposes", and also the "Bill to Provide for an Inventory of the Water Resources of the United States". Attendance 65.

Cleveland.—February 14, 1928. This was a dinner meeting held at Bohanon and Haines Restaurant. Among other business matters, a committee was authorized to report on the advisability of offering a prize for the most meritorious thesis written during the current school year by a member of the Student Chapter at Case School of Applied Science. Attendance 10.

Colorado.—February 24, 1928. A special dinner meeting of the Section was held at the University Club, at Denver, in honor of Messrs. F. A. Banks, Construction Engineer, Nyssa, Ore., D. C. Henny, Consulting Engineer, Portland, Ore., Charles H. Paul, Consulting Engineer, Dayton, Ohio, and A. J. Wiley, Consulting Engineer, Boise, Idaho. R. F. Walter, Chief Engineer of the United States Bureau of Reclamation, acted as Toastmaster. Mr. Banks, who had charge of the construction of the American Falls Dam for the Bureau of Reclamation, gave an interesting description of the various problems involved in moving the Town of American Falls, Idaho, mentioning briefly the construction of the 385-ft. concrete dam which he is about to begin on the Owyhee Irrigation Project of Eastern Oregon. Mr. Paul told of the flood prevention works and the maintenance problems encountered by the Miami Conservancy District at Dayton, followed by Mr. Henny who spoke on the engineering work and the harbor problems of the City of Portland. In conclusion, Mr. Wiley gave a very interesting account of his recent trip to India, during which he traveled through the Punjab country as Consulting Engineer for the British Government, with Col. H. W. Nicholson, who was recently a guest of the Section. Attendance 39.

Dayton.—February 13, 1928. The principal speaker at a noon meeting was W. W. Morehouse, Director of the Dayton Department of Water, who discussed the main features of the Sewage Disposal Plant now being constructed by the City. Director Charles H. Paul then spoke briefly on the World War Memorial at Louvain University. An announcement was made of a plan to award Annual Prizes to members of the Student Chapters of Antioch College and the University of Dayton; these prizes are to consist of the entrance fee for Junior Membership in the Society to two members of the graduating class in each of the Student Chapters mentioned. A resolution was passed in favor of the Newton Bill, providing for an inventory of the water resources of the United States. Attendance 45.

* For list of Local Section Officers, Rules, etc., see 1927 Year Book, p. 104.

March 5, 1928. At a noon meeting held at the Engineers' Club, the guest and speaker was Willard T. Chevalier, M. Am. Soc. C. E., General Manager of the Civil Engineering Publications of the McGraw-Hill Publishing Company, New York, N. Y., who spoke on the necessity for the Engineer to combine with his technical thinking and practice the economic and social phases of his activities. A "Bill to Provide for the Re-Organization of the Public Health Activities of the Government and for Other Purposes" was recommended to the local members of Congress for their support. Attendance 29.

Iowa.—February 7, 1928. At a meeting held at Waterloo, five-minute talks on the activities of the Student Chapters were given by Donnelly Black, President of the University of Iowa Student Chapter, and Walt C. Ohlsen, President of the Iowa State College Student Chapter. First Lieut. Mark M. Boatner, Jr., Corps of Engineers, U. S. Army, then spoke on "The Geography and Hydrography of the Lower Mississippi Valley". Written discussions of the "Flood Control Papers" read before the Columbus Meeting of the Society and printed in the December and January number of *Proceedings* were presented by Professors Q. C. Ayres* and S. M. Woodward, and Messrs. W. J. Schlick and C. H. Young. An oral discussion followed. Attendance 40.

Miami.—January 25, 1928. At the Annual Meeting of the Section the following officers were elected for 1928: President, C. S. Nichols; Secretary, R. H. Wilson; and Directors, J. P. Duffy, O. A. Sandquist, R. W. Reed and M. B. Garris.

North Carolina.—January 27, 1928. The following officers were elected for 1928: President, J. E. Willoughby; First Vice-President, H. E. Miller; Second Vice-President, P. C. Painter; and Secretary-Treasurer, Thorndike Saville.

Northeastern.—January 28, 1928. Following a luncheon at the Annual Meeting held at the Engineers Club, Boston, Mass., the reports of officers and committees were received. After these had been accepted, the following officers were elected for 1928: President, Sturgis H. Thorndike;† Vice-President, Richard K. Hale; Secretary-Treasurer, Charles W. Banks; and Members of Executive Committee, Messrs. John C. Chase and Howard A. Gray. Mr. Otis E. Hovey, of New York, N. Y., gave an address in which he showed the progress of the Society by comparing figures of ten and five years ago with those of the present time. He also referred to the award of the first medal from the Rudolph Hering die, which was presented to Mr. Harrison P. Eddy. Mr. Eddy then gave a brief account of the Annual Meeting of the Society held in New York on January 18 to 20. Attendance 44.

Oklahoma.—The following officers will serve for 1928: President, B. S. Myers; First Vice-President, Charles Schultz; Second Vice-President, J. F. Brookes; and Secretary-Treasurer, C. E. Bretz.

Sacramento.—January 24, 1928. Professor Frank Adams, of the University of California, addressed the Section concerning his recent work in Pal-

* *Proceedings*, Am. Soc. C. E., March, 1928, Papers and Discussions, p. 902.

† Mr. Thorndike died February 16, 1928.

estine. Professor Adams was a member of the Committee sent by Jewish bankers to make an economic investigation of the Zionist Colonies which have been established in Palestine. Attendance 37.

January 31, 1928. In response to a request from the City Council, the Section recommended three engineers, from which one is to be selected to make an investigation of recently constructed sewers. George B. McDougall, Chief of the Division of Architecture, of the State Department of Public Works, addressed the Section on "The Work of the State Architect". Attendance 29.

February 7, 1928. This was a joint meeting with the Sacramento Chapter of the American Association of Engineers and the Engineers and Architects Club of Sacramento. Members of the City Planning Board were guests of the Section and presented the "Major Street Plan for Sacramento", which the City will be asked to adopt. Attendance 64.

February 14, 1928. This meeting consisted chiefly of the adoption of By-Laws for the Section. Attendance 25.

February 21, 1928. Mr. E. B. Debler, of the Denver Office of the U. S. Reclamation Service, addressed the Section, choosing as his subject "The Work of the United States Reclamation Service". Attendance 24.

San Francisco.—December 20, 1927. A dinner meeting was held at the Engineers' Club at which various communications and committee reports were given. An account of the Oakland Estuary Excursion of the Section on October 29, 1927, was presented, which told of the work being carried on in the Oakland-Alameda Estuary Subway, and of the sinking of the final and closing section of the tube. The following officers were elected for 1928: President, W. H. Kirkbride; and Vice-President, H. D. Dewell, after which the retiring President, Mr. N. A. Eckart, made a brief speech thanking the Section for its support throughout the year. The technical program consisted of five-minute talks by Mr. Harmon E. Davis, on "An Undergraduate's Viewpoint on Engineering", and "Some Interesting Highway Studies by the United States Bureau of Public Roads" by Mr. R. S. Tuttle. The main subject of the evening was a discussion of "The Mokelumne Water Supply Project for the East Bay Municipal Utility District", by Arthur P. Davis, Chief Engineer, and Frank W. Hanna, Hydraulic Engineer, the latter's paper including "Technical Features of Pardee Dam". Further discussion followed. Attendance 150.

Progress Reports of Committees of Technical Divisions

Report of the Duty of Water Committee of the Irrigation Division on the Consumptive Use of Water in Irrigation*

Synopsis

This report proposes detailed definitions of the consumptive use of water in irrigation. It also calls attention to differences between the basic meaning of consumptive use and its application to the farm, the project, and the valley. Common difficulties in making a dependable determination of consumptive use are enumerated and briefly discussed. Experimental observations of consumptive use of water in typical irrigated valleys of the West are reported.

Introductory

The rapid growth of American irrigation during the first quarter of the Twentieth Century has developed a keen public interest in a study of the disposal of irrigation water. The pioneers in irrigation had little opportunity fully to ascertain what became of the water which they applied to their lands. That they lost some water by surface run-off was obvious; that some water was absorbed by the crops they grew was likewise apparent; but that large quantities of water percolated deeply into the dry soil was to them merely speculation, if, indeed, such losses were suspected at all. However, the gradual rise of water-tables, with resulting enlargement of natural springs and the development of new springs and the seepage return to flood-water channels, to small creeks, and, finally, to rivers, gave increasing evidence concerning the magnitude of losses of water through deep percolation. Moreover, it was found through experience that much less water need be applied to the farms to produce profitable crops than was formerly believed necessary, and the areas of land successfully irrigated by the water from a given stream were greatly increased without any apparent increase in the water supply. Obviously, such increase in area of irrigated land could not continue without limit, some water being actually consumed by the growing crops.

Definitions and Analysis

Gross duty of water, head-gate diversions, and net duty are familiar terms concerning water uses, but "consumptive use" is a term of recent origin, and should not be confused with the net duty on land and other terms used in discussions of duty of water.

* This report represents a part of the results of the work undertaken by the Duty of Water Committee of the Irrigation Division. A progress report on this subject was presented at the meeting of the Irrigation Division at Salt Lake City, Utah, July 9, 1925, by O. W. Israelsen, Assoc. M. Am. Soc. C. E. The present report has been prepared by Prof. Israelsen and includes, in addition to the material previously presented, further experimental data on consumptive use in different areas and analysis of the results.

Results of the work of the Committee on the "Determination of Duty of Water in Water-Right Adjudications" were published as Paper No. 1620, in *Transactions*, Am. Soc. C. E., Vol. 90 (1927), p. 1074.

Some engineers have used the term, consumptive use, as restricted to "valley consumption", or net depletion of river flow, whereas others have used it to include water used from all sources, or total water consumption, irrespective of whether it is from river water, rainfall, carry-over soil moisture, or absorption from ground-water. It is believed that the use of the definitions given in this report will avoid confusion in the study of consumptive use of water, and comparisons of engineering data will thus be placed more nearly on a common basis.

The term, consumptive use of water, was used in Colorado nearly two decades ago by John E. Field, M. Am. Soc. C. E., then State Engineer. It has since been used in Court testimony concerning water supply studies in the Laramie River inter-state water litigation between Wyoming and Colorado; in the North Platte River Co-Operative Report between the U. S. Reclamation Service and the State of Wyoming; in the Rio Grande Basin water supply studies of the U. S. Reclamation Service; and in the Colorado River Compact deliberations in the several Western States. It has heretofore been defined by R. I. Meeker, M. Am. Soc. C. E., of this Committee, as:

"The permanent water loss incident to irrigation of large tracts of land. Generally speaking, consumptive use is the difference between the inflow and the outflow below any specific area under consideration, or the difference between the amount of water diverted and the amount returning to a stream. With respect to an entire river system, it is the net amount after deducting the outflow from the inflow."

To add convenience and brevity to the following definitions and analysis of consumptive use proposed by the Committee, mathematical symbols are employed and mathematical methods are followed, despite the fact that the equations are of a comparatively simple form.

Symbols Used.—The meaning of each of the more important symbols is fully given subsequently. For convenience of reference, the meaning of these symbols is briefly as follows:

Let,

U = consumptive use.
U_f = farm consumptive use.
U_p = project consumptive use.
U_v = valley consumptive use.
Q_h = quantity of available heat, in day-degrees, during crop year.
e = evaporation from water surfaces.
m = mean seasonal soil moisture content.
s = the soil with all its influencing factors, notably potash, phosphorus, lime, humus, and nitrifying power.
c = the kind of crop.
y = the yield of crop.
D_f = deep percolation losses from the farm.
H_f = the total quantity of water supplied the farm.
R_f = surface run-off from the farm.

D_p, H_p, and R_p = project deep percolation, project water supply, and project run-off, respectively.
E_p = project evaporation losses.
E_v = valley evaporation losses.
D_v, H_v, and R_v = valley deep percolation, valley water supply, and valley outflow, respectively.

Consumptive Use in a Basic Sense.—The consumptive use, U, is here defined as the quantity of water, in acre-feet per cropped acre per year, absorbed by the crop and transpired or used directly in the building of plant tissue, together with that evaporated from the crop-producing land.*

The direct source of "consumed" water is the water in the soil in any form that crops can absorb it. The indirect sources of consumed water are those parts of the precipitation and of irrigation water which are stored in the soil in such depths and for such time as to permit direct absorption by crop roots, together with such water as may be obtained by the crop roots from the ground-water after such water is raised to the plant root zone by capillary action. The consumptive use as herein defined is, therefore, equal to the total evapo-transpiration plus the water used in the building of plant tissue.

It is natural to inquire concerning the factors which determine the magnitude of U. A statement of the major influencing factors is made in the following equation:

$$U = \int (Q_h, e, m, s, c, y)\dagger \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

It is apparent that most of the factors which influence the magnitude of U are themselves variable. The number of variables may be reduced somewhat under specified conditions; for example, if the soil of a farm is liberally supplied with organic matter and all the essential plant-food elements, so that the yield of a particular crop will be limited by the quantity of heat available and not by lack of moisture or plant food, it is possible to eliminate the last four factors in Equation (1) and write:

$$U = \int (Q_h, e) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1a)$$

In the light of the foregoing statements, it is unreasonable to expect that a precise experimental determination of U will give a definite magnitude that can always be considered rigorously correct. Engineers must use dependable approximations of the magnitude of U.

Knowledge concerning the magnitude of U is dependent on further analysis. Does U indicate consumptive use per acre on a particular farm, an irrigation project, or in an irrigated valley? Further definitions are clearly necessary.

* The consumptive use, as here defined, is not rigorously a correct application of the term, "consumptive," since the water which passes out of the crop leaves is not truly consumed. It is merely converted by the plant and the energy of the sun from the liquid to the gaseous phase. However, for the purposes of this report, water vapor in the atmosphere is considered beyond direct recovery by practical means, and hence the conversion of liquid water into water vapor is considered herein as consumptive use.

† Plant diseases and insect pests may reduce crop yield, y, without proportionately reducing consumptive use, U. Likewise, inefficient farm practices may change the relation between U and y.

Let U_f = "farm consumptive use";
U_p = "project consumptive use"; and
U_v = "valley consumptive use".

Definitions of each of these three modifications of consumptive use are considered desirable and are, therefore, proposed herewith.

It seems reasonable to assume that the public may expect the individual irrigator to account for all the water which goes on to his farm. With respect to a particular farm, the water applied is disposed of by consumptive use, plus surface run-off, plus losses from the farm by deep percolation.

Farm Consumptive Use.—Let D_f = deep percolation farm loss, in acre-feet per cropped acre per crop year. This loss usually cannot be measured with precision by direct means. Then, by definition, as used in this report,

$$U_f = U + D_f \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

It is important to distinguish between U_f and a related quantity, H_f, which is defined as follows:

Let H_f = the sum of: (*a*) the quantity of water delivered at the farm, plus (*b*) the water taken from moisture stored in the capillary form before planting, or during the non-growing season, plus (*c*) the crop-year rainfall, plus (*d*) the amount absorbed from the ground-water—all in terms of acre-feet per cropped acre per crop year.

Let R_f = surface run-off from a farm, in acre-feet per cropped acre per crop year. Then, by equating the water going on to the farm plus rainfall and draft on soil moisture plus the quantity absorbed from the ground-water, (H_f), to farm consumptive use, (U_f) plus farm run-off, (R_f), we have:

$$U_f = H_f - R_f \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Equation (3) gives an indirect means of arriving at the farm consumptive use.

Project Consumptive Use.—In order to define U_p and indicate an indirect means of measuring it, the following quantities are introduced:

Let D_p = the non-measurable deep-soil percolation and capillary losses, in acre-feet per project acre per crop year, from any project.

Let H_p = the sum of: (*a*) The area of measurable surface water which flows into the project plus (*b*) the crop seasonal draft on soil moisture plus (*c*) the depletion of ground-water plus (*d*) the crop-season rainfall, also in acre-feet per project acre per crop year. Items (*b*) and (*c*) may be positive or negative.

Let R_p = the sum of: (*a*) The surface run-off losses, in acre-feet per project acre per crop year plus (*b*) such deep-soil percolation losses as contribute directly to a measurable rise in the height of the water-table plus (*c*) the deep-soil percolation losses as may re-appear in natural or artificial channels at the boundaries of a project.

Let E_p = the evaporation losses, in acre-feet per project acre during the crop year, from the non-cropped area within the boundaries of the project, such as roadways, barnyards, towns, etc., together with the transpiration from natural non-crop vegetation within the project boundaries.

Then, by definition,

$$U_p = U + D_p + E_p \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)^*$$

By equating inflow to outflow plus change in moisture content:

$$H_p = (U + D_p + E_p) + R_p = U_p + R_p$$

and, therefore,

$$U_p = H_p - R_p \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Equation (5) gives an indirect means of determining the project consumptive use. It is important to note from Equation (4) that the project consumptive use includes two factors which are difficult to determine directly, namely, D_p and E_p. With poorly prepared land, porous soil, small irrigation streams, and great distances between the head ditches, D_p is likely to become excessive, possibly greater than U. It is not probably extravagant to state that, in general, project managers should endeavor to reduce $(D_p + E_p)$ to a minimum and thus decrease U_p until it closely approaches U. On some high land projects, D_p may be recovered and used on lower neighboring land. On such projects it is less objectionable to have D_p large although excessive deep percolation losses on high land usually decreases the productivity of lower areas.

Valley Consumptive Use.—In order to define U_v and indicate an indirect means of measuring it, some further quantities are needed.

Let D_v = the non-recoverable deep-soil percolation losses during the crop year recorded, in acre-feet per acre, based on the total area of irrigated land in the valley, that is, on the sum of the gross areas of projects within the valley.

Let E_v = the evaporation and transpiration losses from the non-cropped area of the valley per crop year, in acre-feet, divided by the gross area of irrigated land in the valley.

By definition as here used:

$$U_v = U + D_v + E_v \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

However, as in the case of a project, it is very difficult to measure D_v and E_v by direct means. This is particularly true of D_v, and, hence, other more easily measured quantities are introduced.

Let H_v = the sum of the following: (*a*) The acre-feet of water entering the valley in measurable channels during the crop year; (*b*) the crop-year draft on soil moisture; (*c*) the crop-year rainfall; and (*d*) the water derived from the ground-water divided by the irrigated valley area, as defined under D_v and E_v.

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* Provided a relatively small area of the land within the boundaries of an irrigation project or valley is irrigated, the common practice of determining project or valley consumptive use by dividing the difference between the inflow above and outflow below the tract in question by the area of the tract is misleading even if the corrections for contribution of rainfall, draft on soil moisture, and absorption from ground-water are properly made. To illustrate:

Let W = the total water diminution on the tract, in acre-feet;
A_c = the cropped area, in acres; and,
A_p = the area within the project boundaries, in acres.
From Equation (4),

$$W = U A_c + (D_p + E_p) A_p \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (a)$$

Dividing Equation (*a*) by A_p,

$$\frac{W}{A_p} = \frac{A_c}{A_p} U + (D_p + E_p) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (b)$$

If the ratio, $\frac{A_c}{A_p}$, is small, approaching, say, one-half, then $\frac{W}{A_p}$ is not equal to U_p, as here defined. Equation (*b*) shows the importance of measuring A_c with a fair degree of precision.

Let R_v = the measurable outflow, in acre-feet, divided by the irrigated valley area, as defined for D_v and E_v.

By equating inflow plus rainfall plus draft on soil moisture and groundwater (H_v) to valley consumptive use (U_v) plus outflow (R_v), we have:

$$H_v = (U + D_v + E_v) + R_v - R_v + U_v$$

therefore,

$$U_v = H_v - R_v \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

It is very important that consumptive use as here defined, either in its basic sense or as measured on a farm, a project, or in a valley, should not be considered as representing the quantity of water which the farmer, the project manager, or the valley community should be permitted to divert for irrigation purposes. In localities of very low crop-year rainfall, deep loam soils, favorable topography, reservoir storage for water when not needed, and other favorable conditions, it is possible that the quantities, R_f, R_p, and R_v, will be reduced to a minimum, thus making H_f, H_p, and H_v approach U_f, U_p, and U_v, respectively, as Equations (3), (5), and (7) indicate would be the case. In general, however, such favorable conditions do not exist, and, consequently, there is no simple relation between the quantity of water necessary properly to irrigate a farm, a project, or a valley, and the respective consumptive uses.

Common Difficulties

Some of the more common difficulties in measuring consumptive uses under the cases considered, together with notes concerning their variability, are briefly given, after which some actual measurements are reported. The factors which cause variability in U at a particular place have been given in Equation (1). It is obvious that all the factors in the right-hand member of Equation (1) vary greatly from place to place. Based on elaborate experiments in Nebraska, Kiesselbach (10)* concluded that "there is no such thing as a definite water requirement which is constant for any kind of crop"; and, similarly, there is no definite consumptive use. In Equation (2), D_f depends on:

(*a*) The quantity of irrigation water applied in each irrigation;
(*b*) The uniformity of distribution;
(*c*) The frequency of irrigation;
(*d*) The length of land irrigated in a single run and the size of stream used;
(*e*) The texture of the soil and subsoil;
(*f*) The depth to the water-table;
(*g*) The dryness of soil between the water-table and the zone of root action, provided the water-table is very deep;
(*h*) The kind of crop and depth of root zone; and,
(*i*) The moisture conductivity of the soil and other less important factors.

In many localities, D_f was large during the early years of irrigation, but is now relatively small because: (1) The dry desert soil to great depths has been fully moistened through the years of irrigation; (2) the land is better prepared for applying water; and (3) general improvement in irrigation

* Reference is made by number to literature cited at the end of the report.

methods has been made. The quantity, D_p, of Equation (4) is likely to be larger than D_f of Equation (2) since it includes deep percolation from canals, ditches, streets, yards, ponds, borrow-pits, and sloughs. It may be high on one project and negligible on a neighboring lower project.

To measure the evaporation and transpiration losses from non-cropped areas by direct means the engineer can measure the areas for which such losses occur and make an approximation. Relative to the $(U + D)$-quantities, such quantities are usually very small.

It seems advantageous, however, to endeavor to approximate the consumptive use on the farm, project, and valley areas by indirect means as indicated in Equations (3), (5), and (7). More detailed consideration of the difficulties of measurement and sources of error in the elements of moisture supply and run-off are, therefore, desirable.

Provided the farm, project, or valley considered has a deep uniform soil and deep water-table, the elements of supply may be measured with fair precision, but on gravelly or greatly variable soils the draft on soil moisture cannot be effectively measured. Moreover, moisture loss cannot be precisely measured on large projects or in large valleys without prohibitive expense; it can only be estimated. The rainfall may vary greatly from point to point; and it is, therefore, essential carefully to estimate percentage inaccuracy in the elements of supply which may result from rainfall variation, provided the rainfall factor is comparatively large. Possibly a still greater source of error is inflowing ground-water from neighboring high land, measurements of which are sometimes impractical.

In some of the larger valleys of the West, of which many in California, Colorado, and Arizona are typical, the inflowing ground-water is of great importance. Water from melting snows and rains in the mountain ranges may sink into the coarse textured soil of the valley rim immediately after leaving the canyons. These waters gradually move underground toward the middle or lower areas of the valley and may here form high water-tables, thus supplying water for crop production. Under such conditions, this factor may make it impractical to obtain dependable measurements of the project or valley water supply.

In general, the measurement of surface run-off from the farm is neither difficult nor very expensive. Likewise, the measurement of project run-off depends on the particular project. On some projects situated as long strips of side-hill land, it is difficult to measure run-off. The measurement of run-off from valleys, in general, is not so difficult as it is from projects. Some valleys have deep canyon drainage outlets over impervious floors, and in such cases the run-off can be measured without serious difficulty. Some valleys have surface-flow and ground-water flow outlet drainage, but if it is evident that the surface flow greatly predominates, the measurement may permit a close approximation of valley consumptive use.

That the dependability of measurement of the consumptive use rests on a complete analysis of all these factors is not likely to be over-emphasized. Moreover, reports of consumptive use, for the farm, for the project, or for the valley, or, indeed, for any other area, should not be given great weight, unless

they are accompanied by complete and detailed descriptions of the conditions under which they were made. Doubtless, in some localities, the relative magnitudes of the inaccessible inflow and outflow below the ground surface, or those under other conditions which render measurements impracticable, are so great as to make computations of project or valley consumptive use of little value if not really dangerous. On the contrary, the need for economic utilization of water from all sources and the urgency of being able to predict with a fair degree of accuracy the areas that may be adequately served by a given water supply seem fully to justify extraordinary efforts toward increasing the ability to measure consumptive use under specified conditions.

Experimental Measurements

The literature on duty of water is voluminous. The Federal Department of Agriculture, through its Bureaus of Public Roads and of Plant Industry; the Department of the Interior, through the Bureau of Reclamation and the Geological Survey; the State Agricultural Experiment Stations; the State Engineers' Offices; and some private agencies are annually contributing substantial amounts of time and energy to a solution of the duty-of-water problem. In Canada, also, very careful study is being made of duty of water by public and private agencies. Some of the experiments thus conducted give a fair basis for determinations of the consumptive use and the farm consumptive use. Many duty-of-water studies have been conducted without measuring the water obtained from capillary soil moisture, and, indeed, some have failed to report the crop-year rainfall. Consequently, reference is here made only to those experiments which seem most directly to contribute toward a determination of consumptive use both in its basic sense, U, and in its modified meanings, for the farm, the project, and the valley, respectively.

Consumptive Use, U, as Determined from Tank or Pot Experiments

Hammatt (2) and Stevens (19) have endeavored to determine the consumptive use from the crop yield on a given area and estimates of the evapo-transpiration ratio. Most of the evapo-transpiration studies have been conducted in tanks or potometers. Kiesselbach (10) found that the limitation of the amount of soil used, because of the small capacity of the potometer, may be a great source of error in pot experiments. It seriously affects not only the transpiration relationships, but the entire development of the plant.

Other difficulties in determination of consumptive use by means of potometers are:

(*a*) Obtaining the same atmospheric environmental conditions around pots as exist in ordinary cropped land.
(*b*) Obtaining the same number of plants per unit area of land as occur under field conditions.
(*c*) Getting the soil into tanks in the same physical conditions as exist in the field, thus permitting the same aeration and water movement.

The influence of these factors on the consumptive use is great enough to render the pot method of determining such use of questionable value.

Consumptive Use as Determined on Field Experimental Plots

Direct measurements of consumptive use in field plots are believed to be more dependable than measurements with pots or tanks. In order to permit measurements in the field, it is clearly necessary to use land in which the water-table is at a considerable distance below the surface, because when working with small field plots it is usually impractical to measure the quantity of water absorbed by the crop from the ground-water. It is also necessary that the irrigation water be applied in small units not to exceed a depth of 5 in. in a single irrigation on ordinary soils. Even a smaller quantity will often result in percolation beyond the depth of feeding roots in coarse-textured soils. Either very large unit applications of water at ordinary time intervals, or excessively frequent irrigations resulting in the maintenance of a high moisture content, is likely to cause an appreciable downward movement of moisture in the gravitational or capillary form, and thus give apparent values for the consumptive use higher than the true values. It is impracticable, by direct means, to measure the amount of such downward movement, and hence an attempt to measure the consumptive use under these conditions may give, in reality, the farm consumptive use. When the percolate equals zero, the farm consumptive use equals the consumptive use; therefore, it follows that the consumptive use equals the supply less the surface run-off. In most of the field determinations of net duty of water, the run-off has been either carefully measured or reduced to zero by the proper preparation of the experimental plots. The supply factors, in general, have not been measured with precision even on plots where the great depth of the water-table has precluded the possibility of the crop receiving any ground-water. This is due to the fact that precise measurements of the quantity of water taken from capillary soil-moisture storage is practical only in comparatively homogeneous soils free from gravel, and that even under the most favorable soil conditions dependable soil moisture tests add greatly to the cost of duty-of-water studies. There is, however, a growing need for more thorough duty-of-water studies in which the consumptive use will be determined for different conditions. In some such studies the consumptive use has been either determined or closely approximated, and of these the following are typical.

Widtsoe's Utah Work.—Widtsoe (23,24) pioneered the measurement of consumptive use in field plots at the Utah Agricultural Experiment Station, beginning in 1902. This work was done on land having a water-table about 75 ft. below the surface; and, hence, it is reasonably safe to conclude that the crops obtained no ground-water and that the crop-season rainfall, the draft on stored capillary soil moisture, and the irrigation water furnished all the water to which the crops had access. There was no run-off from the experimental plots used by Widtsoe, $R_f = 0$. The deep percolation losses, D_f, were not measured. If these losses are assumed to be negligible, then, $U = H_f$, that is, the sum of the quantities, (*a*), (*b*), and (*c*), of H_f as used in Equation (3). Widtsoe measured these sources of water for 14 crops during the 10-year period, 1902-11, inclusive. Results for the 7 crops on which most of the work was done, are given here. The crop-season rainfall

used by Widtsoe was 0.42 ft. and the seasonal draft on capillary moisture in the upper 8 ft. of soil, varied from 0.10 ft. for corn to 0.83 ft. for alfalfa. Quantities of irrigation water were applied, varying from 0.42 ft. to 5.00 ft., and wide variations in crop yields were obtained. In the studies by the Committee the yields obtained by Widtsoe were plotted against the total water used, and, as a basis for arriving at the consumptive use, those yields were selected which appear to be most profitable. With nearly every crop, the yield increased rapidly to a certain point with increase of total water used, and then either decreased with further increase in water or increased very slowly, and at this "break in the curve", the value of U was taken. The results are given in Table 1.

TABLE 1.—CONSUMPTIVE USE AS DETERMINED ON FIELD PLOTS BY WIDTSOE AT THE UTAH AGRICULTURAL EXPERIMENT STATION, IN CACHE VALLEY, UTAH.

Crop.	Number of single trials.	Yield, in bushels, or tons per acre.*	Consumptive use, in acre-feet per acre.
Sugar-beets	152	21.3	2.5
Potatoes	124	267.0	2.2
Alfalfa	49	4.7	3.3
Corn	81	99.2	2.5
Wheat	142	45.7	2.4
Oats	29	80.7	2.5

* Yields are given in tons per acre for sugar-beets and alfalfa and bushels per acre for the remainder of the crops.

Widtsoe's work indicates the importance of yield in determining the consumptive use. It is also important to keep in mind the fact that deep percolation losses from the plots on which Widtsoe worked would result in observed magnitudes of U higher than the true ones. It is far more probable that the given values of U are too high rather than too low.

Snelson's Alberta Work.—Working on field plots in Brooks, Alberta, Canada, Snelson (18) used moderate quantities of water in single applications and made careful measurements of soil moisture to a depth of 6 ft. at the beginning and the end of the growing season. Under his methods percolation loss in all probability was very small if not zero, and hence it seems safe to assume that U is equal to U_f. If percolation losses were zero, then according to Snelson's experiments with wheat on the more fertile soil the consumptive use varied from 0.85 ft. to 1.82 ft. as the crop yield varied from 10 to 50 bushels per acre. For oats on the more fertile plots the consumptive use ranged from 0.72 ft. to 1.75 ft. as the yield varied from 40 to 135 bushels per acre. Barley required a consumptive use from 1.25 to 1.60 ft. for yields ranging from 40 to 51 bushels per acre, and for alfalfa the use varied from 1.00 to 2.62 ft. for yields ranging from 1.0 to 5.7 tons per acre.

Powers' Oregon Work.—Powers (16, 17) has made many field plot measurements of consumptive use in Oregon. Experimenting with alfalfa in the Willamette Valley during 1911, using moderate irrigation he found values from 1.4 to 2.0 ft., accompanying yields of 4.1 to 5.2 tons per acre.

The consumptive use for clover was approximately the same as that for alfalfa. Moisture determinations were made to a depth of 6 ft. at the outset in the Willamette Valley work, but as most of the borings showed a water penetration to only 4 ft., the later borings were not made below this depth except in connection with a few very heavy irrigations. Powers was convinced that there was "practically no loss by percolation" apparently because dry soil was frequently encountered in the lower depths and also because these lower depths in many instances gained in moisture content during the period following one irrigation and preceding the next following. It is doubtful whether this is conclusive since the increase in the lower depths may have been caused by a movement of capillary water downward from the moist surface to the drier sections below. If such were the case, some percolation probably occurred and Powers' measurements would represent U_f instead of U. If, on the other hand, the moisture did rise in significant quantities from below the zone of soil sampling, then the value of the consumptive use as measured by Powers is too small as there was an unmeasured source of water. In reporting the Western Oregon work, Powers is silent concerning the depth of the water-table.

Further measurements were made in Eastern Oregon by Powers (17), but it is beyond the scope of this report to give them in detail.

Utah Work by Harris.—Further field plot work at the Utah Agricultural Experiment Station by Harris (6) and associates from 1911 to 1919 gives additional information concerning consumptive use. The results of this work, together with the work done by Widtsoe, have been reported in detail in fifteen Station *Bulletins* which were published as the work progressed. Finally, in one paper (6), Harris has brought together the results of 17 years' work. This *Bulletin* contains six charts, each representing a different crop, which show the relation between the yield and the quantity of water applied. Two curves are platted on each chart, the actual average yields for the different irrigations being shown by dotted lines, and the average found by weighting the results according to the number of tests are shown by heavy lines. Harris did not report the seasonal draft of each crop on the soil moisture. For purposes of comparison, this has been assumed to be the same as that found by Widtsoe. Moreover, to make the results still further comparable, the depths of water applied, according to the heavy lines of the charts prepared by Harris, have been selected corresponding to the respective crop yields used in connection with Widtsoe's data, that is, for 21.3 tons of sugar-beets, 267.0 bushels of potatoes, etc. On these bases, Table 2 has been prepared.

These values show fair agreement with those obtained from Widtsoe's work, except for the alfalfa and oats. According to Fig. 5 of Utah Station *Bulletin 173,* a yield of alfalfa of 4.3 tons per acre would require the same consumptive use as found by Widtsoe for 4.7 tons, namely, 3.3 ft. The maximum yield of oats according to the 17 years' work reported by Harris is slightly less than the 80.7 bushels per acre used in Widtsoe's work. A yield of 74 bushels per acre, according to the curves by Harris, would have been

produced by a consumptive use of 2.5 ft., the quantity required to produce 80.7 bushels in Widtsoe's work.

TABLE 2.—CONSUMPTIVE USE APPROXIMATIONS BASED ON THE FIELD PLOT WORK OF WIDTSOE AND HARRIS AT THE UTAH AGRICULTURAL EXPERIMENT STATION.

Crops.	Yield, in tons or bushels per acre.	Depth of water applied, in feet.	Depth of soil moisture and rainfall used, in feet.	Consumptive use, in acre-feet per acre.
Sugar-beets	21.3	1.50	0.86	2.4
Potatoes	207.0	1.67	0.53	2.2
Alfalfa	4.7	3.33	1.25	4.6
Corn	99.2	1.67	0.52	2.2
Wheat	45.7	1.33	1.15	2.5
Oats	80.7	2.33	0.81	3.1

FARM CONSUMPTIVE USE

Lewis' Idaho Work.—Lewis (11) measured the quantity of water used by nine important crops in the Snake River Valley, near Twin Falls, Idaho. He divided his observations into two groups: (1) Those on the better plats that produced high yields; and (2) those on which average yields were produced. His data are summarized in Table 3. It will be noted that in the better plots the seven grain crops and also the potatoes consumed less than 2 acre-ft. per acre. The alfalfa consumed the largest quantity and the clover the next largest, the average for all the crops being 1.75 ft. on the better plots and 1.53 ft. on the average plots. It is probable that these magnitudes represent the farm consumptive use, U_f, for the Twin Falls area more nearly than the consumptive use, U, since the experimental conditions very likely permitted some deep percolation.

TABLE 3.—FARM CONSUMPTIVE USE (U_f) AS MEASURED ON FIELD PLOTS IN THE SNAKE RIVER VALLEY, IDAHO, BY LEWIS.

Crop.	U_f on plots of high production.	U_f on plots of average production.
Wheat	1.78	1.18
Oats	1.84	1.45
Barley	1.68	1.58
Peas	1.66	1.36
Beans	1.20	1.20
Corn	0.96	1.29
Potatoes	1.63	1.60
Clover	2.14	1.54
Alfalfa	2.89	2.55
Mean, if crops are given equal weights	1.75	1.53

Hemphill's Colorado Work.—Working in the Cache la Poudre Valley, Colorado, during 1916 and 1917, Hemphill (8) measured the water applied to twenty-five farms. The run-off, R_f, is not given for each farm, but the

average, R_f, was 6% of the quantity applied. Deducting 6% of the quantity for maximum crops to arrive at the quantity of irrigation water held on each farm and adding arbitrarily an allowance of 0.3 ft. for moisture absorbed from the stored winter precipitation and adding, further, 0.92 ft. for rainfall from April 1 to September 30, there results the farm consumptive use as given in Table 4. How closely the farm consumptive use, as given in Table 4, approaches the consumptive use is conjectural, as the magnitude of the percolation losses is not known and as it is subject to greater variation in actual farm irrigation than in field plot experiments heretofore reported.

TABLE 4.—FARM CONSUMPTIVE USE AS DETERMINED BY HEMPHILL IN CACHE LA POUDRE VALLEY, COLORADO.

Crops.	Maximum yield, in tons, or bushels per acre.	Farm consumptive use for maximum yield per acre.	Average yield, in tons, or bushels per acre.	Farm consumptive use for average yield per acre.
Sugar-beets	15.1	3.6	12.6	3.0
Potatoes	390.0	4.2	230.1	3.3
Alfalfa	4.0	5.8	2.8	3.7
Barley	60.0	3.4	40.7	2.8
Wheat	45.0	3.1	27.7	2.1
Oats	80.0	3.6	48.1	1.4

Investigations of the net duty of water in Sevier Valley, Utah, by Israelsen and Winsor (9) during the 7-year period, 1914 to 1920, gives some information concerning farm consumptive use. In these experiments, the quantities of water found necessary to deliver to the farm for sugar-beets, potatoes, and alfalfa, excluding farm run-off, R_f, were 2.5, 2.0, and 2.8 acre-ft. per acre, respectively. The crop-season rainfall was 0.3 ft., and assuming a draft on the soil moisture of 0.3 ft., the farm consumptive use, U_f, is as follows: Sugar-beets, 3.1; potatoes, 2.6; and alfalfa, 3.4 acre-ft. per acre. Further reference is made to these quantities in connection with a report for U_v for the Sevier Valley.

PROJECT CONSUMPTIVE USE

It is important to remember that farm and project consumptive use in general are likely to be, respectively, equal to or greater than the consumptive use, and also that during the early years of irrigation the difference between these quantities is likely to be greater than after many years of farming under the canal. The following are examples of some approximations of project consumptive use.

Steward's Idaho Work.—In the Boise Valley, Idaho, in connection with drainage operations, Steward (20) found project consumptive use on the Pioneer District Drainage area (approximately 13 500 acres) by subtracting the drainage run-off from the sum of the rainfall plus the irrigation water applied, a difference of 2.13 acre-ft. in 1916 and 2.18 acre-ft., in 1917. On the Twin Falls South Side Project, in 1915, Sloan (20) found, by working on a 12 000-acre tract, a project consumptive use of 2.95 acre-ft.

Steward and Paul (21) made a careful study of sources and disposition of water on the Nampa Meridian Drainage Districts in 1917. These investigators found on the Mason and Indian Creek tracts, having an area of approximately 50 000 acres, a transpiration plus evaporation of 1.9 ft. from April to October, inclusive. The factors of supply, H_p, of Equation (5) were as follows: (*a*) The inflow consisted largely of irrigation water and was 4.16 acre-ft. per acre; (*b*) the draft on soil moisture was neglected, probably without greatly influencing the results; (*c*) the absorption from the ground-water was not estimated; and (*d*) the crop-season rainfall was 0.36 ft. The factors in project run-off of Equation (5) were measured as follows: (*a*) Run-off was measured at all drainage outlets, and amounted to 2.02 acre-ft. per acre; (*b*) the deep-soil percolation losses were measured by making direct observations on water-table fluctuations and amounted to 0.60 acre-ft. per acre; and (*c*) the deep-soil percolation losses which re-appeared at the boundaries of the project, were measured as waters commingled with those in Factor (*a*). Applying Equation (5), the approximate project consumptive use, $U_p = (4.16 + 0.36) - (2.02 + 0.60) = 1.90$. A complete report of the work of Steward and Paul is beyond the scope of this report.

Crandall's Snake River Valley Work.—Crandall (1) measured consumptive use in the Lower Snake River Valley. He considered an irrigated area of nearly 90 000 acres in 1917 and of more than 100 000 acres in 1918. Using three different methods, he obtained close agreement. These methods were:

1.—Measurement of percolation losses from the irrigated land by finding the annual increase in discharge of springs below the tract.
2.—By making soil moisture determinations before and after irrigations.
3.—By computations from water-requirement studies under somewhat similar climatic and soil conditions.

A brief review of each method and of the results obtained are given as follows.

1.—Crandall's Measurement of Percolation Losses

The normal annual discharge of the springs as determined by measurements for a period of 5 years prior to irrigation was 3 885 sec.-ft. By allowing a 2-month lag period—the time required for the seepage losses to appear in the springs—Crandall found the increases in the spring discharges from all irrigation sources and from deep percolation from farms, and knowing the total deliveries to irrigators, he determined the consumptive use as shown further in Table 5.

Crandall believes that delay in water deliveries until the middle of May in 1917, due to maintenance work, is the cause of the smaller consumptive use during the first year of the measurements.

2.—Crandall's Soil Moisture Measurements

By taking samples of soil before and after irrigation, Crandall found that the moisture content of the forage-crop soils increased from 10 to 20% of the dry weight of the soil and that the moisture content of the grain-crop soils

increased from 8 to 20%—each to a depth of 4 ft. The water-free soil weighed 80 lb. per cu. ft.; hence, the upper 4 ft. of the forage-crop soils absorbed 0.5 ft. per irrigation, or 2.5 ft. for the five irrigations; the same depth of the grain-crop soils absorbed 1.8 ft. from three irrigations, or 0.6 ft. in each irrigation. About 54% of the project was in forage crops and 45% in grain crops; hence, the consumption of irrigation water on this basis was 2.2 ft., and adding the crop-season rainfall, 0.15 ft., and the draft on soil moisture, about 0.25 ft., the consumptive use becomes 2.6 acre-ft. per acre.

TABLE 5.—PROJECT CONSUMPTIVE USE AS DETERMINED BY CRANDALL ON THE TWIN FALLS NORTH SIDE PROJECT, SNAKE RIVER VALLEY, IDAHO.

	From June, 1917, to May, 1918, included, in acre feet.	From June, 1918, to May, 1919, included, in acre-feet.
Increase in springs discharge from all irrigation sources	816 800	878 900
Losses from canal system by seepage plus spring water contributions from other irrigation projects	612 627	650 439
Contributions to spring discharge by seepage from irrigated lands	204 173	228 461
Deliveries to irrigators less run-off or recovered wastes	389 909	484 838
Irrigation water consumed by the crops: Total on the project	185 736	256 377
Irrigation water consumed by the crops: Acre-feet per acre	2.1	2.5
Rainfall during crop season, April to September inclusive	0.15	0.15
Draft on moisture in soil	0.25	0.25
Project consumptive use, U_p	2.5	2.9

3.—Crandall's Computations on Basis of Water-Requirement Studies

At the beginning of this Committee's consideration of experimental observations, the difficulties and common sources of error in the use of water requirement studies from pot or tank experiments as a basis for consumptive use determinations over large areas were briefly enumerated. That determinations of the consumptive use on this basis could be considered only as approximations was also asserted. Despite these facts, it is interesting to note the agreement obtained by Crandall using this method with the two methods just presented. The analysis made by him is quoted herewith from his report:

"Detailed experiments have been made by Widtsoe at Logan, Utah, under climatic and irrigation conditions similar to those existing on the North Side tract, to determine the amount of water required to produce a pound of dried crop. The amount of water so required varies with the different factors including kind of crops, degree of fertility, amount of water applied, amount of soil moisture at beginning of season, etc. Detailed results are published in *Bulletin 285* of the U. S. Department of Agriculture and *Bulletin 116* of the Utah Experiment Station. For the conditions existing on the North Side Tract during 1917, these experiments indicate that approximately 1 300 lb. of water would be required to produce a pound of dried crop. This includes the transpiration requirements of the plants and evaporation losses from the fields. The average yield of the hay and pasture crops during 1917 was 4½ tons per acre. As the hay when cured in the stack contains about 15% moisture, this is equivalent to about 7 600 lb. of dry matter per acre for the hay and pasture crops. The average yield of wheat was determined as approximately 25 bushels per acre and the straw as 1½ times the weight of the grain

making a total production of 3 800 lb. of crop per acre for wheat. As the wheat and straw contain about 10% moisture, this is equivalent to 3 400 lb. of dry matter per acre, which is taken as the average yield for crops aside from hay and pasture. The low average grain yields were due to the large acreage on which grain was planted late in the spring as a nurse crop for alfalfa.

"The average yield over the entire tract for all crops was then approximately 5 600 lb. of dry matter per acre. At an average water cost of 1 300 lb. of water per pound of dry matter this would require for its production 2.65 acre-ft. of water per acre. This quantity includes the water withdrawn from the moisture stored in the soil and precipitation during the growing season."

The water requirement, 2.65 acre-ft. per acre, is equivalent to the consumptive use as herein defined. It must be noted, however, that percentages of moisture in the hay and in the grain are estimates only, that the probable error in measuring the crop yields is unknown, that the percentage of wheat and straw likewise is estimated and that in the light of these conditions the close agreement of the determinations of the consumptive use by the several methods should not be considered as conclusive evidence of the dependability of the method.

Valley Consumptive Use

In the early years of irrigation of any valley, the valley consumptive use is relatively large because the deep percolation losses, D_v, go to moisten dry soil to great depths and build up the water-table, and are, therefore, temporarily non-recoverable. Moreover, the non-cropped area is relatively large during the early years of irrigation, and losses therefrom are larger than in later years.

Sevier Valley, Utah.—The Sevier Valley, in Utah, is typical of the older irrigated valleys in which deep percolation losses have become very small, since nearly all these losses shortly reach the high water-table which slopes toward the stream channels (or is quickly built up and thus made to slope toward the channels) so that there are very small, if any, non-recoverable losses from percolation. Likewise, the non-cropped area is small, and hence its losses are practically negligible. In this valley it is very probable that the consumptive use is almost equal to valley consumptive use; hence, from Equation (7), $U = H_v - R_v$. The inflow to, and the outflow from, the Sevier Valley for the 7-year period, 1914 to 1920, has been measured by the Utah State Engineer's Office and reported by Ullrich (22). The average annual inflow of the river at Sevier, including the inflow of tributaries from Sevier to Gunnison, for this 7-year period was 295 000 acre-ft., and the average outflow was 211 000 acre-ft., thus leaving 85 000 acre-ft. which was applied to 65 000 acres giving a consumptive use of 1.3 ft. The crop-year rainfall is approximately 0.3 ft. As the mean annual rainfall is only 0.7 ft., the draft by the crops on moisture stored in the soil from winter rains and from ground-water is probably not to exceed 0.3 ft., the quantity previously assumed in connection with the net-duty work. On this basis, therefore, the consumptive use, U, for the Sevier Valley, as herein defined, is 1.9 ft. This value of the consumptive use is much less than farm consumptive use as determined by the Utah Experiment Station for standard crops on a typical soil.

If one-half the irrigated lands of the valley were in alfalfa and one-fourth in sugar-beets and potatoes, respectively, then farm consumptive use, according to the values presented heretofore, would be 3.0 acre-ft. per acre. For crops thus distributed and for yields equal to those of the experimental farm it would mean either that farm percolation $D_f = 1.1$ acre-ft. per acre, since $U_f = U + D_f$ (provided no water entered the valley through underground sources that could not be measured), or that 71 500 acre-ft. percolated into the valley if $D_f = 0$. In all probability the truth lies somewhere between these two extremes, meaning that some unmeasured water entered the valley and that some water was lost by deep percolation from the experimental plots, the sum of the two for the entire valley being approximately 71 500 acre-ft., provided the experimental farm yields were not much greater than those of the valley as a whole.

Cache la Poudre Valley, Colorado.—The Cache la Poudre Valley, in Northern Colorado, is one of the foremost irrigated valleys of that State. Irrigation practice there is diversified, well-balanced as to crop rotation, and economic as to use of water. The need for water has raised water values and forced economy of use in irrigation. A 2-year investigation of irrigation in that area furnishes some valuable information on consumptive use. According to Hemphill the average consumptive use of river water, during the 2-year period of 1916-17, was 1.25 acre-ft. per acre over an area of 220 000 acres net. Adding 0.92 acre-ft. crop-season rainfall which is 80% of the 1.14 acre-ft. mean annual rainfall, gives a valley consumptive use of about 2.17 acre-ft. per acre. Data are not available concerning draft on soil moisture.

Truckee River, Nevada.—In connection with duty-of-water studies on the Truckee River, in Nevada, Harding (3) estimated the valley consumptive use by subtracting the valley outflow at Vista from the inflow at the California-Nevada line. He made estimates also based on direct measurement of drains and found fair agreement for seasonal consumptive use between the two methods. In making monthly comparisons by the two methods the results are less consistent. The gross area of cropped land considered was 27 000 acres, approximately three-fourths of which is cultivated land and the remainder largely wild hay land. The cultivated land produced mostly alfalfa, but also some native grass on land that might have been used for other crops. Based on these studies, Harding concludes that the valley consumptive use during the six months of April to September, inclusive, for 1900-18, including the 0.19 ft. rainfall, is 3 ft., but excluding the draft on soil moisture, if any. The local practice of applying water at frequent intervals in small quantities is considered in part responsible for this high consumptive use. Moreover, the meadow areas are irrigated almost continuously. The irrigation season is about 165 days. A high precision is not claimed for the results, as evidenced in the following comments by Harding:

"The records are not as complete as would be desired, and the resulting consumptive use is higher than would be expected. The area is typical of two cuttings of alfalfa with either a light third cutting or good fall pasturage valley such as occur in the Mountain States."

Columbia River Tributaries.—Parker (14) estimated the average valley consumptive use, exclusive of rainfall, on 12 tributaries of the Columbia River for the "climatic years" 1909-10, 1910-11, and 1911-12. The estimated irrigated acreages during each of the three years were 99 000, 103 000, and 108 000, respectively. It is noteworthy that the magnitudes of consumptive use obtained, namely, 2.9, 2.7, and 2.8, respectively, agree closely, despite significant differences in the run-off.

Methods of Estimating Valley Consumptive Use

Hedke's Method.—It is desirable to estimate the consumptive use of water in irrigation, in different valleys, in advance of complete agricultural development. Recognizing the importance and complexity of the consumptive use problem, Charles R. Hedke, M. Am. Soc. C. E., (7) has investigated the relation of consumptive use of water to the quantity of heat available to the crop during the growing season, and has found substantially that under favorable agricultural conditions the use of water is directly proportional to the use of heat available. The relative approach of the actual agricultural practice to the best practice is designated by Hedke as the "Standard of Agriculture". The application of the direct relation between water consumption and available heat, proposed by Hedke, to a valley in which the agricultural practices are of a high standard, necessitates the following assumptions:

1.—That the heat consumed by a particular crop, during any day or other time period, is determined by the amount of heat available to the crop above the germinating or minimum growing temperature.
2.—That under favorable agricultural practices, each crop consumes water in direct relation to the heat available as defined.
3.—That the soils considered are abundantly supplied with moisture and plant-food so that the yield of a crop will be limited only by the amount of heat available.
4.—That the influence of variations in wind velocity, relative humidity, and vapor pressure on consumptive use of water are relatively small as compared to the influence of available heat.

Under these assumptions, Equation (1*a*) may be written, $U = f(Q_h)$, or simply $U = K\,Q_h$, which is the basic relation assumed by Hedke.

To determine Q_h, Hedke subtracts the minimum growing temperature of each crop from the mean temperature of each month, or fraction thereof, within the growing season. The result thus obtained, multiplied by the number of days in the month, represents the available heat units in day-degrees for a particular crop during the month considered. The sum of the heat units available to each crop for each month gives the available heat units for the crop-year. Hedke found in the Cache la Poudre Valley of Colorado in 1916 that heat was available to alfalfa during the eight months of March to October, whereas, to potatoes it was available only from May to September, inclusive. To find the total heat units available on a project, the heat units available to each of the crops are multiplied by the proportion of the project lands in the respective crops, and the sum of the products thus obtained gives the available heat units for the project.

Hedke has applied his proposed principle to several typical valleys and has obtained some gratifying results. The result of his work in the Cache la Poudre Valley and its application to the San Luis Valley, in Colorado, and the Rio Grande Valley, in New Mexico, suggests that Q_h is a predominating factor in fixing the magnitude of the consumptive use.

Hedke defines consumptive use as the "total amount of water transpired incidental to farming an area"; thus the inclusion of the water evaporated from the crop-producing land is implied, but not specifically stated. He states further that the consumptive use "is here covered by the net depletion from the stream plus one-half the total yearly rainfall". However, his applications do not show that "net depletion" includes the crop-year draft on soil moisture plus the water derived from the ground-water, both of which should be considered as indicated in this Committee's enumeration of the elements of supply, as used in Equation (7).

Based on Hemphill's measurements of valley consumptive use for the Cache la Poudre Valley, and using the equation, $U_v = K\,Q_h$, Hedke has found that $K = 0.000423$, approximately. Having the magnitude of K, Hedke considers it possible to determine the valley consumptive use for the highest "standard of agriculture" in any valley in which dependable crop distribution and temperature records are available. His analysis of crops and temperatures in the Middle Rio Grande Valley shows a normal available heat, Q_h, of 6 200 day-degrees, and applying the value of K, finds, $U_v = 0.000423 \times 6\,200 = 2.6$ acre-ft. Considering the Rio Grande Project, he finds that $Q_h = 6\,800$, and, hence, $U_v = 0.000423 \times 6\,800 = 2.9$ acre-ft. By deducting the "effective precipitation" from each of these values, he arrives at an estimate of the net depletion in the stream system. The application of these estimates without modification is of necessity based on an actual or an assumed high "standard of agriculture" in the Rio Grande Valley and on the Rio Grande Project similar to that of the Cache la Poudre Valley of Colorado.

In this connection it is essential to remember that Hedke urges the importance of making careful observations concerning the relative agricultural practices in different valleys for which information is available, concerning the total available heat termed by him the "thermal location", and that the magnitude of U_v, as computed from a known constant and the available heat, be reduced in proportion to the lack of attainment of the highest possible standard of agriculture. The dependability of such reduction in the computed valley consumptive use obviously rests on the experience and judgment of the engineer. The method proposed by Hedke, therefore, seems to give the greatest promise in those valleys where a high standard of agriculture has been attained, thus eliminating the necessity of applying the so-called "personal equation of judgment and experience". Obviously, the method may likewise be applied to the newer irrigated valleys under an assumed ultimate distribution of crops and high agricultural standard for the purpose of estimating the consumptive use of water which will occur after the agricultural development of the valley concerned has been completed.

Harding's Method.—Harding has studied project and valley consumptive use on extensive areas in the San Joaquin Valley, California (4, 5). A complete report of his California investigations is beyond the scope of this report, which is restricted to a brief statement of the extent of the work, a description of his methods, and a summary of his observations.

The Kings River area included about 700 000 acres of irrigated land and the Kaweah area, 184 000 acres. Harding measured the factors of water supply and run-off of Equation (5), as follows:

(*a*) The channel inflow is based on records of current-meter rating stations.
(*b*) The crop seasonal draft on soil moisture was not measured; in effect, however, it was reduced to a minimum by so modifying other factors as to provide an equivalent elevation of water-table.
(*c*) The necessity of computing the quantity of water absorbed from the ground-water was eliminated by the same method as the moisture content in Factor (*b*).
(*d*) The crop-seasonal rainfall on the projects investigated is negligible.
(*e*) There were no appreciable surface run-off losses.
(*f*) The need for measurements of deep percolation losses was eliminated by determining graphically the quantity of canal water needed to maintain the water-table at a constant normal elevation (see Fig. 1).

A similar statement applies to Harding's method of determining H_v and R_v in Equation (7).

Harding's Method as Applied to the Kings River Area.—The conditions in some of the areas served by the Kings River (4) are such as to furnish a basis on which the consumptive use may be estimated. These conditions are most favorable in the Fresno, Consolidated, and Alta Irrigation Districts. For these districts adequate records of ground-water fluctuation were available for 1922 to 1925, which include one year of more than normal run-off, one year of about 80%, one of about 70%, and one of about 25% run-off. The relative diversions vary even more widely than the run-off due to the later priorities of rights of the Consolidated and Alta Districts. Adequate diversion records are also available for the districts as a whole and for their main laterals.

In connection with the engineering studies made by the State Engineer's Office of the Kings River Water Conservation District, Harding made a detailed analysis of the ground-water records.

The rainfall at Fresno averages 0.81 ft. annually, and occurs mainly in the winter months. Diversions for irrigation extend from February to October, varying with the available water supply, the period of diversion being longer in the Fresno District due to its earlier priority of right.

The method of analysis consisted in determining the seasonal ground water fluctuation and comparing it with the acre-feet of water conveyed into the area, per acre of cropped land. In all these areas there is extensive pumping for irrigation. Some land was supplied with water entirely by pumping from local ground-water; other land was furnished canal water when available

and pumped water during the remainder of the season. The gross area of farms served was used in estimating consumptive use. As the projects are highly developed, the net area cropped is nearly as large as the gross areas herein used.

The year was divided into two periods, namely, March 1 to November 30 and December 1 to February 28, because an examination of the ground-water fluctuations in the winter indicated no influence from the delivery of water during the preceding irrigation season. The winter fluctuations vary largely with the winter precipitation, but this is probably an indirect relationship, since with larger rainfall there is less irrigation pumping, and there is also some local tributary run-off.

The canal deliveries necessary to maintain the ground-water were taken as the quantities necessary to cause a rise or fall from March 1 to November 30 equal to the fall or rise that would occur from December 1 to February 28 in a year of normal rainfall. The quantities of water delivered to each tract each year, together with the accompanying water-table fluctuations, were plotted as illustrated in Fig. 1, which typifies Harding's method of analyzing consumptive use data. This diagram gives the results obtained, respectively, on the entire area under the Fresno Irrigation District, the Consolidated Irrigation District, and the Alta Irrigation District.

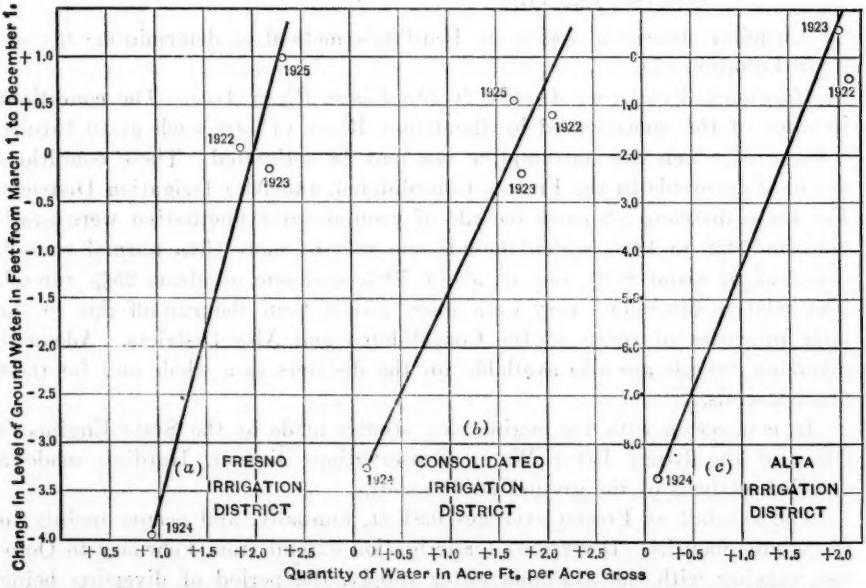

FIG. 1.—RELATION OF VOLUME OF WATER DIVERTED IN AREA TO CHANGE IN LEVEL OF GROUND-WATER.

The summarized results of canal deliveries and ground-water fluctuations for these three areas for 1922 to 1925 are shown in Table 6. The resulting estimated requirements for diversion into each area to supply the consumptive use and maintain the ground-water are also shown in Table 6. These esti-

mates were arrived at by plotting the ground-water fluctuation against the deliveries, as shown in Fig. 1, and selecting the intersections of the line drawn through the resulting points with the axis of zero change in level of ground-water, as representing the deliveries that would be required to supply the consumptive use and maintain the ground-water for the periods, March 1 to December 1. The estimated total annual requirements were based on allowing for the ground-water fluctuations from December 1 to March 1 in years of normal rainfall as previously explained.

TABLE 6.—DIVERSION OF WATER AND GROUND-WATER FLUCTUATIONS IN FRESNO, CONSOLIDATED, AND ALTA IRRIGATION DISTRICTS FROM MARCH 1 TO DECEMBER 1, WITH FLUCTUATIONS FROM DECEMBER 1 TO MARCH 1 IN YEARS OF NORMAL RAINFALL.

Year.	Irrigation District.					
	Fresno.*		Consolidated.		Alta.	
	Diversion into area, in acre-feet per acre, irrigated, March 1 to December 1, in feet.	Average ground-water fluctuation, March 1 to December 1, in feet.	Diversion into area, in acre-feet per acre, irrigated.	Average ground-water fluctuation, March 1 to December 1, in feet.	Diversion into area, in acre-feet per acre, irrigated.	Average ground-water fluctuation, March 1 to December 1, in feet.
1922	1.93	+0.15	2.05	+0.45	2.07	−0.40
1923	2.12	−0.15	1.75	−0.15	2.01	+0.80
1924	0.96	−3.95	0.20	−3.15	0.18	−8.65
1925	2.30	+1.0	1.64	+0.55	1.95	+1.50
Ground-water fluctuation, December 1 to March 1, in season of normal rainfall	.....	+0.3	....	0.0	.....	+0.2
Estimated annual requirement for diversion into area to supply consumptive use and maintain ground-water, in acre-feet per acre irrigated	2.0	.....	1.7	.....	1.9	.....
Crops in percentage of total:						
Trees	29	.....	15	.....	13	.....
Vines	43	.....	60	.....	80	.....
Forage and pasture	19	.....	10	.....	4	.....
Miscellaneous	9	.....	15	.....	3	.....

*Covers only portion of the district served by the Fresno Canal; gross area, 169 000 acres.

The indicated consumptive use as obtained from Table 6 and Fig. 1, is based on the surface diversions into the areas. It does not include any unmeasurable ground-water movement into or out of the area. Ground-water inflow is considered to be relatively small as the areas above these districts are unirrigated and the adjacent Kings River channel shows a gain rather than a loss under normal conditions of supply. Ground-water outflow may occur, although its extent is considered to be relatively small in proportion to the consumptive use so indicated by other records.

In 1922 and 1923, in some parts of each of these three districts the ground-water was within 6 ft. or less of the ground surface. In some areas it rose within less than 4 ft. of the surface. The estimated delivery requirement to maintain the crops and ground-water includes evaporation from the soils in such areas, as well as plant transpiration. The consumptive use indicated may be affected by these conditions. The numerical results presented are considered as illustrating the method used rather than as a final determination of the quantity of the consumptive use of these areas. A final determination will require additional length of record under present ground-water conditions.

In addition to the areas of the district as a whole, the areas served by several of the main laterals were similarly studied. Such areas had varying conditions as to the type of crop grown and ground-water elevations. From these results the following conclusions were drawn by Harding:

"Records to date from different areas indicate, as tentative conclusions, that in areas of trees and vines having limited ground-water outflow, the crop needs for moisture will be supplied by an average annual delivery into the area of about 1⅞ acre-ft. of water per acre of crop. For forage crops an average delivery of 2 to 2¼ acre-ft. of water per acre of crop may be required. For other crop conditions other amounts of supply are found necessary. Where ground-water outflow occurs or where the ground-water is close to the ground surface, larger amounts are required to supply the crops and maintain the ground-water."

Kaweah River Area.—Some data indicating valley consumptive use are given by Harding for the Kaweah (5) River area during 1920 and 1921, the records indicating a valley consumptive use, U_v, of about 2.2 acre-ft. per acre. The crops consisted of approximately 34% orchard and vines, 29% alfalfa, 28% corn and grain, and 9% miscellaneous. There were some areas of high ground-water, but these were relatively small in extent. The climatic conditions were typical of those of the main San Joaquin Valley areas. The ground-water is dependent on the Kaweah River and the diversions therefrom. Available data indicate that the ground-water basin is closed. About 183 500 acres were cropped in a gross area of 365 000 acres.

Meeker's Valley Consumptive Use Studies in Colorado.—Meeker has conducted investigations concerning consumptive use in several typical valleys in Colorado and has also assembled and compiled data for other valleys. His analyses were made with the viewpoint of determining the net depletion of river water by irrigated lands either naturally or artificially drained. Wasteful evaporation from seeped areas was, therefore, excluded as a form of consumption. Re-use of seepage or return waters and water recovered by drainage systems within an area were automatically included and served to decrease the burden on the original river flow. Large irrigated areas were used and records of stream flow were considered of from 5 to 10 years to eliminate minor irregularities of climatic and variations in crops in irrigated lands.

The crop-year draft on soil moisture and the water drawn from ground-water sources, being, respectively, Factors (*b*) and (*d*) of H_v in Equation (7), were not evaluated in Meeker's studies. The values of the valley consumptive use reported herewith, therefore, may be slightly smaller than the actual mag-

nitudes of consumptive use in the respective valleys. Unpublished records supplied the Committee by Meeker contain interesting data concerning gross and net duty of water in 18 river systems, and on 9 of these consumptive-use data are available. The observations on these 9 systems are reported in Table 7.

It will be noted in Column (9) of Table 7 that the consumptive use, defined as dimunition in stream flow, varied from 0.9 acre-ft. per acre per year in the Little Laramie River Basin to 1.3 acre-ft. per acre per year in the Sevier River Basin and on the Boise Project. Column (9*a*) which has been added to Table (7) by the Committee, gives the valley consumptive use as here defined, with the exception noted that there are no measurements of draft on soil moisture or ground-water. Assuming the seasonal draft on soil moisture and ground-water to be 0.3 acre-ft. per acre, as was assumed for the Sevier River Basin, then valley consumptive use varies from 1.5 to 2.2 acre-ft. per acre for the river basins reported in Table 7.

Investigations of the return flow on the Cache la Poudre and South Platte River by Meeker (13) and on the Lower South Platte by Parshall (15) give further evidence concerning consumptive use. In a résumé of factors affecting return flow, Meeker places the consumptive use (not including crop-season rainfall or draft on soil moisture) at 1.25 ft. and reports that from 35 to 65% of waters diverted for irrigation appear as return flow in the Colorado streams mentioned.

Meeker's conclusion, based on rather extensive investigations, is as follows:

"The conclusion from these studies and from comparisons with the natural return flow from large older irrigated areas is that the amount of water actually consumed by crops is relatively small compared with the amount diverted, and further that with efficient drainage on an irrigated project, the actual plant consumption has decidedly low limits regardless of the water applied."

Discussion.

It has been pointed out that many independent factors influence the valley consumptive use. However, there is urgent need for arriving at some relatively simple method of estimating its magnitude. Therefore, in order further to study the merits of Hedke's proposal, the determinations of valley consumptive use made by Crandall, Harding, and Meeker are assembled in Table 8. Each river system is designated by a number given in Column (1). The minimum growing temperatures given in Column (5) were selected on the basis of the minimum growing temperatures for the predominating crops in the respective areas. Column (6) contains the names of the U. S. Weather Bureau stations from which temperature records were taken as the basis for computing the available heat as given in Column (8).

The data presented in Columns (7) and (8) are platted in Fig. 2, which suggests a straight line relation between U_v and Q_h. The slope of the line in Fig. 2, or the magnitude of K in the equation, $U_v = KQ_h$, is 0.00039, which is about 8% less than the magnitude of K as determined from Hedke's analysis of Cache la Poudre experiments. This is considered a close agreement, particularly when it is recognized that the minimum growing temperatures of

TABLE 7.—CONSUMPTIVE USE OF WATER IN IRRIGATION.

River basin.	State.	Average elevation of land, above sea level, in feet.	Mean annual temperature, in degrees.	Mean annual rainfall, in inches.	Rainfall during growing season, in inches.	Head-gate diversion, in acre-feet per acre per year.	Net duty on land, in acre-feet per acre per year.	Consumptive use, irrigation water, in acre-feet per acre per year.	Consumptive use, including crop-year rainfall, (U_c).	Area, in acres.	Growing season, average number of days between frosts.	Authority and remarks.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(9a)	(10)	(11)	(12)
1. Little Laramie: Hatton to Two Rivers	Wyoming..	7 300	40	14	4	(*a*)	(*a*)	0.90	1.2	28 000	95	12-year record, 1912-23, inclusive, includes some waste into Big Basin by Park Ditch; automatic gauge, Upper Station, 1912-14; automatic gauge, Lower Station, 1913-23.
2. Little Laramie: Hatton to Two Rivers	Wyoming..	7 300	40	14	4	(*a*)	(*a*)	1.00	1.3	28 000	95	R. I. Meeker, 3-year record (1912-13-14), Laramie River investigations; automatic records of water above and below; irrigated area determined from reconnaissance survey; (*a*) chiefly meadows, heavily flooded compact area.
3. North Platte: North Park	Colorado...	8 200	38	10	2	(*b*)	(*b*)	1.00	1.8	120 000	60	1.00 assumed and adopted for North Platte Co-operative Report by Conkling and Meeker (1919), see Vol. 2; (*b*) chiefly meadows; freely flooded.
4. Boise: Mason Creek Area, Boise Project, U. S. Reclamation Service...	Idaho.....	.....	50	11	3	4.1	.....	1.20	1.4	13 550	155	U. S. Reclamation Service special investigation on area with drainage system; drainage recovery, 2.89 acre-ft. per acre per year, see North Platte Co-operative Report, Vol. 2, p. 120 (1919); work by Steward, Paul, *et al.*
5. South Platte: Kersey to Julesburg..	Colorado...	4 100	48	14	9	2.7	1.8	1.15	1.9	229 000	145	Comp. by R. I. Meeker from special investigation by Co-operative, U. S. Department of Agriculture, Colorado Agricultural Experiment Station, and State Engineering of Colorado, 1919-20. Colorado Agricultural Experiment Station, *Bulletin 279* (December, 1922); water-table still rising and return flow increasing; includes reservoir evaporation.

TABLE 7.—(*Continued.*)

River basin.	State.	Average elevation of land, above sea level, in feet.	Mean annual temperature, in degrees.	Mean annual rainfall, in inches.	Rainfall during growing season, in inches.	Head-gate diversion, in acre-feet per acre per year.	Net duty on land, in acre-feet per acre per year.	Consumptive use irrigation water, in acre-feet per acre per year.	Consumptive use, including crop-year rainfall, (U_c).	Area, in acres.	Growing season, average number days between frosts.	Authority and remarks.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(9a)	(10)	(11)	(12)
6. Cache la Poudre: Poudre Valley....	Colorado...	5 000	48	14	7	1.9	1.5	1.25	1.8	220 000	135	Special 2-year investigation by Hemphill of the U. S. Dept. of Agriculture, 1916-17, *Bulletin 1026* (1922), pp. 24, 25; footnote on page 25 states credit for return seepage from Poudre Valley Land into South Platte would reduce slightly; the 1.25 figure determined includes reservoir evaporation.
7. South Platte: South Platte and Tributary Valleys.....	Colorado...	5 700–8 500	49	14	7	2.0±	.....	1.25±	1.8	1 100 000	145	Water supply study and analysis for 10-year period, by R. I. Meeker, 1912-21. (See *Engineering News-Record*, July 20, 1922, pp. 105-109). Water-table still rising and return flow increasing; future consumptive use will be less than 1.25 acre ft. per year; includes evaporation losses from 300 reservoirs.
8. Sevier: Sevier to Gunnison.....	Utah	5 200	48	8	2	.....	.....	1.30	1.5	65 000	110	Exhibit A, Appendix, Salt Lake City Hearings, Colorado River Commission, 1922; C. J. Ullrich, eight-year record; 1915-22.
9. Boise: Part Boise Project, U. S. Reclamation Service...	Idaho	2 500±	50	11	3	.....	3.6	1.30	1.6	49 000	155	U. S. Reclamation Service Special Investigation on area with drainage system; drainage recovery, 2.29 acre-ft. per acre per year; 3-year period; see North Platte Cooperative Report, Vol. 2 (1919), p. 120; excludes seepage from Deer Flat Reservoir.

so many crops under such varied conditions can only be approximated. The Snake River results seem to be the most erratic. It is hoped that this report will elicit additional data on valley consumptive use, particularly from areas of high mean annual temperatures, so that the straight line relation indicated by Fig. 2 may be affirmed or modified.

TABLE 8.—MAGNITUDES OF VALLEY CONSUMPTIVE USE, U_v, AND AVAILABLE HEAT, Q_h, FOR TYPICAL IRRIGATED VALLEYS IN THE WEST.

No. (1)	River system. (2)	Years' work. (3)	State. (4)	Minimum growing temperature, in degrees Fahrenheit. (5)	Cities furnishing temperature records. (6)	Valley consumptive use. (7)	Available heat, Q_h. (8)
1	Little Laramie.....	12	Wyoming ..	33	Laramie.....	1.2	3 455
2	Little Laramie.....	3	Wyoming ..	33	Laramie.....	1.3	3 465
3	Boise Project, Mason Creek.....	..	Idaho.....	36	Boise, Caldwell, Meridian.	1.4	4 357
4	Cache la Poudre....	2	Colorado ...	..	Fort Collins, Greeley.....	1.8	4 150
5	South Platte.....	10	Colorado ...	36	Julesburg, Sterling, Fort Morgan.....	1.8	4 523
6	Boise Project.....	3	Idaho.....	36	Boise, Caldwell, Meridian.	1.6	4 357
7	Sevier River.....	8	Utah	36	Richfield, Marysvale	1.5	3 828
8	South Platte.....	2	.....	36	(See No. 5)	1.9	4 523
9	Snake River Twin Falls Project.....	2	Idaho.....	36	Twin Falls, Shoshone	2.6	4 035
10	Kings.....	4	California..	42	Fresno, Hanford.....	2.0	7 903
11	Kaweah	4	California..	42	Visalia, Tulare, Lindsay..	2.2	7 751
12	Truckee and Reno ..	..	Nevada.....	36	Reno	3.0	5 150

SUMMARY AND CONCLUSION

1.—The term, "consumptive use of water", has been given an important place in engineering literature.

2.—Definitions of consumptive use are proposed in this report both in its basic sense and with respect to the area concerned, whether a farm, a project, or a valley.

3.—Some of the common difficulties in measuring consumptive use are enumerated.

4.—That measurement of project and valley consumptive use under some physical conditions is impractical is indicated.

5.—Investigations concerning consumptive use, as made in California, Colorado, Idaho, Nevada, Nebraska, Oregon, and Utah, and in Alberta, Canada, are briefly reviewed.

6.—The engineering reports and publications reviewed contain information which is considered valuable as a guide to approximations of consumptive use. If the factors affecting the consumptive use do not vary greatly, and particularly if the crop yield is approximately the same throughout a valley, as on experimental plots within the valley, then the valley consumptive use must be either equal to or greater than the net consumptive use. It, therefore,

seems reasonable to believe that quantities of valley consumptive use, U_v, which are less than the net consumptive use, U, if obtained by careful measure-

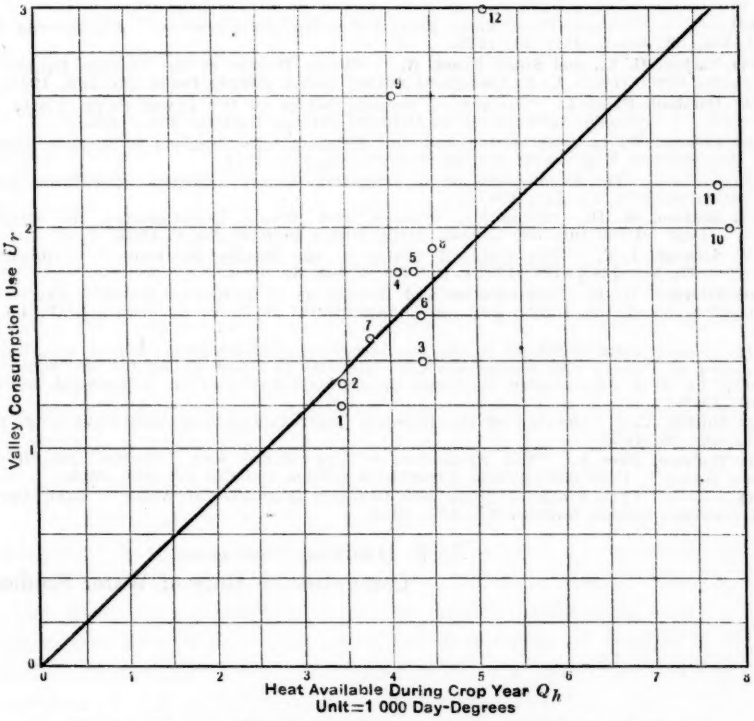

FIG. 2.—VALLEY CONSUMPTIVE USE OF WATER ON TYPICAL PROJECT AS RELATED TO AVAILABLE HEAT.

ments, indicate that the soil conditions and crop yields for the valley are too low, and that if the average yields for the valley are increased to those secured on experimental plots, the valley consumptive use will also be increased.

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Committee on Duty of Water Studies.

Progress Report of the Committee of the Sanitary Engineering Division on Filtering Materials for Water and Sewage Works*

The Committee on Filtering Materials for Water and Sewage Works was appointed in May, 1925. During 1927 two meetings were held, one in June, at Chicago, Ill., and the second on December 3, at Cleveland, Ohio.

The Committee has continued the studies with reference to methods of testing and selecting materials and has extended the collection of data pertaining to experience with filter materials for water work and with fine-grained filter material for sewage work.

The assembling of existing data covering experience with the use of various filter materials and the results of various investigations and tests has proved to be a rather slow process. However, the Committee believes that some very worth-while data have been collected and that in due time these will be supplemented with sufficient additional information and experience data so that some definite procedures can be formulated to serve as guides in the selection of the proper materials for use as filter media in water and sewage works.

Methods of Testing and Selecting Filter Materials

Considerable interest has developed with reference to methods and tests to be used in the selection of proper materials for filter media. The Committee has had excellent co-operation from the sanitary officers in various States, arrangements having been made by the Departments of Health in some instances to do a small amount of testing work in connection with the general supervision of the selection of filter materials. Some of the crushed stone companies have organized testing laboratories for the purpose of checking their product as to its fitness for use as filter media. The slag industry is also undertaking certain investigational work along the same line.

The number of sewage trickling filters being built is increasing rapidly, and larger filters are being built. The quantities of materials required for use as filter media in these installations are a considerable item in the total cost, and their proper selection is well worth consideration.

A discussion is included herewith as Appendix I covering the methods used in the past for selecting the filtering materials for a number of typical trickling filters. It appears that no standard methods have been developed for selection on the basis of cost considerations and availability rather than on the basis of comparative merit.

George B. Gascoigne, M. Am. Soc. C. E., has developed tentative procedures for taking samples and making tests for use in the selection of coarse-grained filter materials. These tentatively proposed procedures are outlined in Appendix II and Appendix III. The Committee submits these investigations with the hope that it will be a step toward the development of more standardized methods in the selection of filter materials.

* Presented at the meeting of the Sanitary Engineering Division, January 19, 1928.

The test methods suggested may be more comprehensive than will finally be found to be necessary. It appears best to have the list of tests include some which later might prove to be of little value rather than take a chance of omitting those which might prove to be of considerable value.

The Committee is strongly of the opinion that a considerable amount of investigational work, including laboratory tests on many samples of material, must be done before any definite conclusions can be drawn as to proper methods for sampling, the relative value of various tests, and the characteristics of the filter material as indicated by the tests. The Committee suggests that such work is worth while and should be undertaken. The work involves the collection of many samples of filter materials having known records of service in existing trickling filter plants; some of the samples to be of materials which have proved satisfactory in service over a number of years, and others to be of like materials which have proved unsatisfactory under similar service conditions.

The results of such a series of tests should indicate what physical qualities a particular kind of material, such as limestone, slag, and the like, should have to insure that it will prove to be a satisfactory filter medium.

Fine-Grained Filter Material for Sewage Work

The Committee has limited the investigations of fine-grained materials for sewage work during 1927 to sand sewage filters. N. T. Veatch, Jr., M. Am. Soc. C. E., has handled this investigation and has collected considerable information.

As was done in connection with the investigation of coarse-grained materials, inquiries have been sent to the Chief Sanitary Officer of each State, which inquiries covered general data, such as number and size of plants, requirements in regard to sand grading, etc. The form of these inquiries is shown in Appendix IV. Replies were received from 28 States, with 1 island possession (Hawaii), reporting no plants. Of the 20 remaining States, 4 have no State Sanitary Engineer, or State Sanitary Official with whom the Committee could communicate. Of the 16 States having State Sanitary Engineers, or other Sanitary Officials, from which incomplete or no replies have been received, several have promised to furnish data at a later date.

Detailed inquiry blanks, covering the questions outlined in Appendix IV in the 1926 Progress Report* of this Committee made on January 20, 1927, have been sent to each State Sanitary Engineer from whom a list of plants has been received. A sufficient number of blanks have been sent to cover all plants. A few of the detailed inquiry blanks have been returned with answers, but not a sufficient number to justify either inclusion in this report, or the formation of any conclusions from them. However, sufficient data have been obtained to indicate that there is considerable interest on the part of the State Sanitary Engineers in the States where there are intermittent sand sewage filters in operation.

The general data obtained from the inquiries sent to the State Sanitary Engineers are shown in Table 1. These data, which are not complete, indi-

* *Proceedings*, Am. Soc. C. E., April, 1927, Society Affairs, p. 184.

cate the existence of 297 plants in 18 States, 45 of which are serving industries or institutions. The plants listed are serving probably a total of at least 1 250 000 people, using 1920 Census data for estimating purposes. It is impossible to make an accurate estimate of the number of people being served until answers to the detailed inquiries are received.

TABLE 1.—NUMBER OF INSTALLATIONS REPORTED WITH GRADING OF FILTERING MATERIALS REQUIRED BY STATE BOARDS OF HEALTH.

State.	NUMBER OF PLANTS.			SAND GRADING REQUIRED BY STATE BOARD OF HEALTH.	
	Municipal.	Industrial or institutional.	Total.	Uniform coefficient.	Effective size.
Alabama		1	1	None.	None.
Arizona	1	1	2	None.	None.
Arkansas			*		
California	5		5	None.	None.
Colorado			*		
Connecticut	11	1	12	Less than 3.5	0.30 to 0.40
Delaware			*		
Florida			*		
Georgia			*		
Idaho			*		
Illinois			*		
Indiana			*		
Iowa	114		114	Less than 2.5	0.40 to 0.50
Kansas	28		28	Less than 2.5	0.30 to 0.50
Kentucky			*		
Louisiana			*		
Maine			*		
Maryland	4	5	9	Less than 3.0	0.35 to 0.50
Massachusetts	25		25	None.	None.
Michigan	9	2	11	Low as possible.	0.20 to 0.35
Minnesota			*		
Mississippi	1		1	None.	None.
Missouri	1		1	Less than 3.5	0.30 to 0.50
Montana	4		4	None.	None.
New Hampshire			*		
New Jersey			*		
New Mexico		1	1	None.	None.
New York	15		15	Less than 3.0	0.25 to 0.40
North Carolina			*		
Ohio	22		22	Less than 2.5	0.30 to 0.45
Oklahoma			*		
Oregon			*		
Pennsylvania	5	30	35	None.	None.
Rhode Island			*		
South Carolina			*		
South Dakota			*		
Tennessee		3	3	None.	None.
Texas	7	1	8	None.	None.
Utah			*		
Vermont			*		
Virginia					
Washington					
West Virginia					
Wisconsin					
Hawaii					
Total	252	45	297		

* States from which incomplete or no replies were received.

Data already obtained indicate that clogging troubles have been experienced to a greater or less extent in almost every State reporting plants. These troubles have been due to a number of causes, such as to overloading, to certain constituents in the sewage, such as fatty industrial wastes, and to

improperly graded, clay or loam-laden filtering material. It is believed that from the general and detailed inquiries will come data that will enable the selection of representative plants for detailed study, and from this the making of definite recommendations regarding the proper grading of fine-grained filtering materials for sewage works.

During this investigation, considerable interest has been shown in the question of proper material for use in sludge beds, and an investigation and study should be carried on covering this important use of filtering material.

Filtering Materials for Water Work

A general inquiry has been sent to the State Sanitary Engineers with reference to depth and size of sand for water filters. The answers to these inquiries indicate that there is no close agreement as to the proper sand. In many States no regulatory standards have been formulated covering filter sand. Some States have prescribed certain standards, but there is a wide variation as to size and uniformity and to a lesser extent as to the depth prescribed.

In deciding upon the size and depth of filters engineers have been guided by precedent established in other places rather than by the requirements of the particular water to be treated. The Committee has considered the advisability of making tests using small glass-tube test filters to obtain data bearing on the question of proper sand size and depth.

It was decided to ask a number of cities throughout the country to co-operate with the Committee in conducting a series of experiments, using a battery of small glass filters, which should be operated in conjunction with one of the large filter units of the plant at which the experiment is to be conducted. The following cities have already agreed to co-operate in the conducting of these experiments:

Chicago, Ill.	Cincinnati, Ohio	Cleveland, Ohio
Denver, Colo.	Detroit, Mich.	Indianapolis, Ind.
Omaha, Nebr.	Providence, R. I.	Grand Rapids, Mich.
Sacramento, Calif.	St. Louis, Mo.	Washington, D. C.
	Baltimore, Md.	

The responses to this inquiry were unusually prompt and enthusiastic, and it is expected that an interesting set of experiments will be the result. In order to secure uniformity in the matter of sand sizes, the sand will be screened in Baltimore, Md., and sent to the various experimenters.

James W. Armstrong, M. Am. Soc. C. E., has handled the development of the studies with reference to filter sand for water-works. The suggested plan of tests with small glass filters is based on similar tests at Baltimore during the past number of years.

The proposed plan of the experimental work on filter sand for water-works is given in greater detail in Appendix V, together with tentative instructions covering the operation of the test filters.

Recommendations

It is again respectfully recommended that the work of the Committee be continued. From various sources has come evidence of increasing interest in this work. Several lines of inquiry have not been fully developed and appear to be worth continuing.

It is further recommended that sufficient funds be provided to enable the Committee to undertake the suggested program of tests for determining what physical characteristics filter material should have to insure satisfactory service under operating conditions.

Respectfully submitted,

WILLIAM E. STANLEY, *Chairman,*
JAMES W. ARMSTRONG,
W. H. DITTOE,
GEORGE B. GASCOIGNE,
N. T. VEATCH, JR.

January 16, 1928

APPENDIX I

METHODS USED IN THE PAST FOR SELECTING FILTERING MATERIALS FOR SEWAGE TRICKLING FILTERS

Beginning with the first municipal installations in 1908 at Reading, Pa., and Columbus, Ohio, the use of the trickling filter in sewage treatment has developed rapidly until, to-day, it is fast displacing the contact filter. It is estimated that besides the many small installations there are 300 or more trickling filters in service varying in size from 0.1 acre to the largest municipal installation of 30 acres at Baltimore, Md.

The use of large-sized material, that is, say, from 1 in. upward, is a development due to the fact that finer material was found to clog rapidly, thereby not only decreasing the rate of filtration, but also preventing proper aeration which is essential to secure satisfactory results. Furthermore, the higher the rate of filtration permissible the greater the economic advantage.

It is obvious, therefore, that one of the prime essentials in selecting a filtering material is to have it remain permanently of the same size as when placed. Otherwise, if it breaks down, the disadvantages of small sized material will be in evidence and the effectiveness of the filter greatly depreciated.

An investigation of the various installations of trickling filters now in service reveals the fact that in many the filtering material has broken down in varying degrees, while in others no disintegration has occurred even after 10 or 15 years of continuous all-year service. It is pertinent, therefore, to learn what methods were used or tests made in selecting the filtering materials placed in filters in the past.

For this purpose, letters were sent to engineers intimately familiar with the construction of nine typical trickling filters, including the two oldest and two of the most recent, as follows:

Akron, Ohio .....J. E. Root, M. Am. Soc. C. E., Sewerage Engineer.

Baltimore, Md. .....Milton J. Ruark, Sewerage Engineer, and Ezra B. Whitman, M. Am. Soc. C. E., formerly Engineer in Charge of Design and Construction.

Canton, Ohio .....McClaskey and Reese, Consulting Engineers.
Cleveland, Ohio .....George B. Gascoigne, M. Am. Soc. C. E., Consulting Engineer.
Columbus, Ohio .....C. B. Hoover, M. Am. Soc. C. E., Superintendent, Division of Water and Sewage Disposal.
Decatur, Ill. .....William E. Stanley, M. Am. Soc. C. E., Sanitary and Hydraulic Engineer, Pearse, Greeley and Hansen.
Lincoln, Nebr. .....H. P. Letton, Assoc. M. Am. Soc. C. E., Engineer.
Reading, Pa. .....E. Sherman Chase, M. Am. Soc. C. E., formerly Resident Engineer.
Worcester, Mass. .....Ralph G. Lingley, City Engineer.

Excerpts from the replies received to these inquiries will be found appended. Mr. Root's reply is given in full. In addition to these direct replies, data submitted in the inquiry on filtering materials sent out in 1927, were studied with particular reference to the "Reason for Selection" and "What Tests, if Any, Were Made".

A study of the various specifications indicates little change in the basic requirements which in all cases are permanence, cleanliness, and proper sizing. It has always been appreciated that the material must be sound and free from dust and small particles.

Until within the past two or three years apparently little attention has been given to specific tests. Reliance has been placed almost solely on judgment, which, in turn, appears to be based largely on observation.

It is obvious that materials such as trap-rock, quartzite, and certain granites would prove satisfactory when exposed to extreme weather conditions. Consequently, when these materials are available the matter of deciding is greatly simplified. However, in many localities where only limestones, gravel, slag, and local material are available, a decision is not so readily reached. It would appear that the choice has usually been based on observations of the various proposed materials either when used for similar purposes or for ballast. Nevertheless, one of the most important factors in the decision has been availability and cost, oftentimes a material of known inferior quality being used where a satisfactory one was considered prohibitive on account of expense. On the other hand, there have been instances, notably at Lincoln, Nebr., when a known satisfactory material was brought in at considerable expense in preference to local material which failed under tests.

It is interesting to note that the specifications for Columbus, Ohio, written in 1908, and those for Cleveland written in 1925, both stipulated that the material proposed should be equivalent to a sample on display. No better criterion could be asked than that a proposed material should compare favorably with one known to have given satisfactory service. In order that there may

be some laboratory basis on which to foretell the performance, various tests have been proposed. These tests, as can be deduced from the methods used in selecting materials in the past, must serve not only to distinguish between material known to be good, but also to indicate which among various materials of doubtful quality the only ones available will be the most acceptable.

Summarizing, it may be stated that while the basic requirements desired in filtering materials remain unchanged, the past two or three years have seen some progress toward definite procedures, both of inspection and of test, to the end that the specifications may be fulfilled.

Selection, Test, and Inspection of Filtering Material

Akron, Ohio.—The following statement was received from J. E. Root, M. Am. Soc. C. E., relative to the sewage treatment plant at Akron.

The type of plant selected for treating the sewage and industrial wastes from the City of Akron is the Imhoff tank trickling filter plant. The total estimated average daily capacity for which the various units of the plant are designed is 33 000 000 gal., or 51 cu. ft. per sec. The location of the plant is on the Cuyahoga River and approximately 5 miles northwardly from the center of the city. The waters from the Cuyahoga River enter Lake Erie approximately in the heart of the City of Cleveland. The plant is designed for a population of 260 000.

The total area of the trickling filters is 14 acres, subdivided into seven units of 2 acres each, each 2-acre unit being dosed through a twin dosing tank. The depth of filtering material is 10 ft. and the actual loading in persons per acre-foot is 1893. The estimated dosing period is 2 min. and the average resting period is 5.1 min.

The main channels of the under-drainage system are constructed of reinforced concrete. The floor system of the filters consists of a 4-in. reinforced concrete slab on which is placed a clay channel block and on this a grid block manufactured from clay.

The total number of cubic yards of filtering material is 223 000. The average weight of the stone per cubic yard was 2 350 lb., making the total estimated tonnage about 262 000.

Prior to the preparation of specifications for filtering material for the Akron Sewage Treatment Plant, representatives of the City of Akron personally visited and inspected all the leading stone quarries in the limestone district of the northwestern quarter of the State of Ohio as well as the large commercial slag-producing plants in this Youngstown District. Based on information received from and during the inspection, as well as on the experience of the Consulting Engineer, Harrison P. Eddy, M. Am. Soc. C. E., limestone was selected as the filtering material. The desirability of purchasing the material by the city and delivering it to a general contractor for placing in position at the new treatment plant, was also considered as favorable to the city. With these essential considerations in mind the following specifications were developed:

A.—As a Part of the Contract for Furnishing Filtering Material

Contract 8.—Filtering Material

G. 1.—Description.—Under Contract 8 the Contractor shall furnish and deliver, f. o. b. cars, Botzum, Ohio, the Baltimore and Ohio Railroad, broken limestone for filtering material, as specified herein.

G. 2.—Size.—The filtering material shall be of such size that as loaded on the cars not more than five (5) per cent. by weight of any carload will pass through a screen having round holes one (1) inch in diameter and not more than one (1) per cent. by weight of any carload will fail to pass through a screen having round holes two and one-half (2½) inches in diameter. If the filtering material is not to be rescreened by the City at the point of delivery, screen tests will be made on samples collected according to Standard Methods of Sampling Stone for Use as Highway Material, Serial Designation D75-22, of the American Society for Testing Materials. The stone may be sampled either prior to shipment or after delivery.

G. 3.—Rescreening Plant.—Upon delivery the filtering material may, at the option of the Director, be rescreened in an approved plant consisting essentially of a revolving drum screen, five (5) feet in diameter and twenty (20) feet in length, having manganese steel plates of an initial thickness of not less than five-sixteenths (5/16) inch perforated with not less than twelve (12) two and one-half (2½) inch (inside) round holes per square foot of screen surface, and an outer screen or jacket approximately seven (7) feet in diameter and eighteen (18) feet in length having manganese steel plates of an initial thickness of at least one-quarter (¼) inch perforated with not less than fifty-five (55) one (1) inch (inside) round holes per square foot of screen surface. The screen shall be set at an inclination of one and one-half (1½) inches in twelve (12) inches of length, operated at a speed of eleven (11) revolutions per minute and equipped with an automatic mechanical device for regulating the rate of feed as nearly uniformly as practicable to approximately one hundred (100) tons per hour of the filtering material as delivered by the Contractor. The screening plant shall at all times be maintained in an operating condition satisfactory to the Director. The screen or screens shall be provided with new perforated manganese steel plates conforming to the specifications hereinbefore stated whenever any substantial number of holes have become so worn that their maximum diameter measured at any point shall exceed the initial dimensions of the holes herein specified by one-eighth (⅛) inch and the plant shall be operated to secure the screen speed and rate of feed hereinbefore specified.

The screening plant shall be so equipped and operated that those portions of each carload of filtering material which pass through the portion of the screen having one (1) inch openings and which fail to pass through the portion of the screen having two and one-half (2½) inch openings, respectively, shall be satisfactorily collected and accurately weighed upon approved scales which shall, whenever required by the Director, be tested and sealed by the Sealer of Weights and Measures of Summit County.

G. 4.—Quality.—The filtering material shall be clean, sound, hard, limestone rock, free from seams, flat or elongated pieces, and shall conform to the following physical requirements:

Hardness	Not less than 14%
Toughness	Not less than 5%
Wear	Not more than 6%

The stone shall show no signs of checking, cracking, or disintegration by the sodium sulfate test for soundness.

G. 5.—Methods of Testing.—For the hardness test, a core twenty-five (25) millimeters (one (1) inch) in diameter is cut from the solid rock with a diamond drill. The ends of the core are faced off after which the core is dried and

weighed. The specimen is then inserted in the grip of the Dorry machine, leaving ½ inch to 1 inch projecting from the lower end. The grip is then inserted in the sleeve so that the lower end of the specimen rests on the cast-iron disk upon which Ottawa silica sand passing a No. 30 sieve and retained on a No. 40 sieve is fed from the funnels at a uniform rate. The grips should weigh exactly 1 250 grams. The disk is rotated for 500 revolutions at a rate of 30 revolutions per minute, after which the core is taken out, reversed end for end, the 500 revolutions repeated, and the loss, in grams, sustained by the core for the 1 000 revolutions computed. Calling the initial weight of the specimens, A, and the final weight after 1 000 revolutions, B, the coefficient of hardness $= 20 - \frac{(A - B)}{3}$.

The toughness test shall be made in accordance with the Standard Method of Test for Toughness of Rock, Serial Designation D3-18, of the American Society for Testing Materials.

The percentage of wear shall be determined in accordance with the Standard Method of Test for Abrasion of Road Material, Serial Designation D2-08, of the American Society for Testing Materials.

The soundness test consists in immersing a small piece of the rock in a saturated solution of sodium sulfate (Na_2SO_4) for twenty (20) hours, after which it is placed in a drying oven maintained at 100° cent. for four (4) hours. The rock is subjected to twenty (20) successive treatments in this manner.

G. 6.—Tests at Contractor's Plant.—No filtering material shall be shipped by the Contractor until the source has been approved by the Director and such approval shall be subject to cancellation by the Director if the filtering material does not continue to meet the specifications. A period of at least thirty (30) days must be allowed for making inspection and tests prior to acceptance or rejection of the source.

For the purpose of aiding the Contractor in avoiding the shipment of filtering material which will not conform to the specifications, the Director may cause inspection and tests to be made at the Contractor's plant by an inspector or inspectors to be provided by the Director. The Contractor shall furnish at his plant satisfactory laboratory quarters, including heat, light, water, and gas or electricity for heating purposes, for the making of tests on the filtering material.

If any appreciable amount of filtering material loaded on any car shall be found not to comply with the specifications, either before shipment or after delivery, the carload may be rejected by the Director. Any carload of material under suspicion shall be set aside either at the Contractor's plant or at the point of delivery until tests can be made to determine whether or not the material is satisfactory for use. The Contractor shall pay the demurrage on all cars rejected.

G. 7.—Materials to Be Rejected.—All filtering material which on rescreening passes through the one (1) inch screen openings and that which fails to pass through the two and one-half (2½) inch screen openings in excess of five (5) per cent., and one (1) per cent., respectively, as weighed, and any carload of filtering material which fails successfully to pass the tests, shall be rejected and unless removed by the Contractor as hereinafter specified, shall become the property of the City.

G. 8.—Shipping Filtering Material.—On or after June 1, 1926, the Contractor shall be prepared to deliver and on and after September 1, 1926, he shall deliver filtering material at the rate required by the Director. The Director shall give five (5) days' notice of the date upon which a change in rate of delivery is to be required. The rate or rates of delivery shall be such that all of the filtering material to be furnished shall have been delivered on

or before November 30, 1927. The rate of delivery shall be as nearly uniform as possible from day to day and may be required to be changed from time to time to conform to the progress and handling facilities of the Contractor who is placing the filtering material in the trickling filters, but the Contractor shall not be required to deliver filtering material in excess of two thousand (2 000) tons per day. The Director may in cases of emergency order all deliveries suspended whereupon the Contractor shall suspend shipments until ordered to resume them.

G. 9.—Failure to Deliver.—Should the Contractor fail to ship filtering material at the rate at which it is required to be delivered, he shall indemnify and save harmless the City from all claims for damages brought by other Contractors with the City on account of such failure.

G. 10.—Delivery in Excess of Orders.—The Contractor shall be responsible for delivery of filtering material and shall use every available means to secure uniform delivery of filtering material at the rates ordered. In case the Contractor shall make shipment in excess of the rates of delivery ordered, he shall pay any and all demurrage charges resulting from such excess shipments.

G. 11.—Type of Cars.—The filtering material shall be delivered only in twin hopper self-clearing steel cars.

G. 12.—No Payment for Rejected Filtering Material.—No payment will be made to the Contractor for rejected filtering material.

The Contractor shall pay to the City of Akron the sum of fifty (50) cents per ton for all rejected material which shall have been unloaded from cars delivered to the City to cover the cost to the City of handling and rescreening.

G. 13.—Rejected Material to Become Property of City.—The Contractor may, within thirty (30) days after notification by the Director, remove all accumulations of filtering material rejected by the City at his own cost and expense. If, at the expiration of said thirty (30) days, any of said rejected material remains, it shall become the property of the City and no payment therefor will be made.

G. 14.—Measurement and Payment.—The quantity of filtering material to be paid for under this item shall be the actual quantity delivered at Botzum, Ohio, based on the shipping weights as determined by the Railroad, less the weight of material rejected, if any. The unit price specified to be paid per ton under Item 1, shall include the furnishing and delivering of the filtering material, f. o. b. cars, Botzum, Ohio, the Baltimore & Ohio Railroad.

B.—As a Part of the General Contract for Constructing the Sewage Treatment Plant

Item 105.—Placing Filtering Material

105. 1.—Description.—Under Item 105*a*, the Contractor shall place in the trickling filters the filtering material specified herein to be furnished by the City, which work shall include the unloading from cars, furnishing and operating a plant for rescreening, transportation to the site of the work, placing and grading in the filters, storage if any, for the convenience of the Contractor, and disposal of material removed by screening or otherwise.

Under Item 105*b*, the Contractor shall place in the trickling filters the filtering material specified herein to be furnished by the City, including the work specified under Item 105*a*, except furnishing and operating a plant for rescreening and disposal of material removed by screening.

105. 2.—Material Furnished by the City.—The filtering material will be purchased and delivered to the Contractor, f. o. b. cars, Botzum, Ohio, the Baltimore & Ohio Railroad, by the City under a form of contract and specifications which may be seen at the office of the Director.

105. 3.—Rate of Delivery.—Deliveries of filtering material will start on or about September 1, 1926, or at the option of the Contractor, at any time prior thereto, but not earlier than June 1, 1926, and thereafter will be con-

tinued at as nearly a uniform rate as practicable, subject to such reasonable variations in rate as may from time to time be requested by the Contractor for his convenience and as may be permitted by the terms of the contract under which the City shall purchase the filtering material, but the rate or rates at which the filtering material will be delivered shall be such that all of the filtering material required shall have been delivered on or before November 30, 1927.

105. 4.—Rate of Unloading and Disposal.—The Contractor shall be responsible for the unloading and disposal of the filtering material at the rate at which it is delivered to him subject to the limitation that the filtering material shall not be shipped by the contractor furnishing it at a rate in excess of two thousand (2 000) tons per day. The Contractor shall make such progress with the trickling filter floor, underdrains, walls, and accessory structures and work and shall provide such machinery, equipment and labor as will enable him to place and grade in the trickling filter, the filtering material at the rate at which it is delivered except that in case of an emergency he may for his own convenience if approved by the Director, temporarily place filtering material in a satisfactory stock pile from which it shall be placed in the trickling filter as soon as practicable. The Contractor shall pay all railroad demurrage charges except that he shall not pay demurrage on any filtering material shipped on any day in excess of two thousand (2 000) tons nor upon any cars of filtering material which by order of the Director may be set aside for testing prior to acceptance or rejection.

105. 5.—Rescreening.—Under Item 105*a*, the filtering material, immediately before it is placed in the trickling filter, shall be rescreened in a screening plant having a capacity of at least two thousand (2 000) tons in twenty (20) hours when maintained and operated as herein specified.

105. 6.—Screening Plant.—Under Item 105*a*, the Contractor shall furnish, maintain, and operate an approved screening plant consisting essentially of a revolving drum screen, five (5) feet in diameter and twenty (20) feet in length, having manganese steel plates of an initial thickness of not less than five-sixteenths ($\frac{5}{16}$) inch perforated with not less than twelve (12) two and one-half ($2\frac{1}{2}$) inch (inside) round holes per square foot of screen surface, and an outer screen or jacket approximately seven (7) feet in diameter and eighteen (18) feet in length having manganese steel plates of an initial thickness of at least one-quarter ($\frac{1}{4}$) inch perforated with not less than fifty-five (55) one (1) inch (inside) round holes per square foot of screen surface. The screen shall be set at an inclination of one and one-half ($1\frac{1}{2}$) inches in twelve (12) inches of length, operated at a speed of eleven (11) revolutions per minute and equipped with an automatic mechanical device for regulating the rate of feed as nearly uniformly as practicable to approximately one hundred (100) tons per hour of the filtering material delivered to the Contractor. The screening plant shall at all times be maintained in an operating condition satisfactory to the Director. The screen or screens shall be provided with new perforated manganese steel plates conforming to the specifications hereinbefore stated whenever any substantial number of holes have become so worn that their maximum diameter measured at any point shall exceed the initial dimensions of the holes herein specified by one-eighth ($\frac{1}{8}$) inch, and the plant shall be operated to secure the screen speed and rate of feed hereinbefore specified.

The screening plant shall be so equipped and operated that those portions of each carload of filtering material which pass through the portion of the screen having one (1) inch openings and which fail to pass through the portion of the screen having two and one-half ($1\frac{1}{2}$) inch openings, respectively, shall be satisfactorily collected and accurately weighed upon approved scales which shall, whenever required by the Director, be tested and sealed by the Sealer of Weights and Measures of Summit County.

105. 7.—Placing.—The filtering material shall be deposited in the filters in approximately its final position so that rehandling of the material in the filters will be reduced to a minimum.

The filtering material shall not be dropped into the filters. The container used for transporting the filtering material shall be brought as near to the top of the cover blocks or previously deposited filtering material as practicable before dumping.

The Contractor shall take every precaution to prevent the passage of filtering material through the cover blocks into the underdrains while placing the filtering material in the filters, even to the extent of placing by hand a layer of coarse material on the cover blocks. All underdrains shall be left clean and free from obstructions after the filtering material has been placed. All broken cover blocks shall be replaced by the Contractor before being covered with filtering material.

The surface of the filtering material shall be brought to an elevation slightly above the bottom of the trickling filter distributor piping and then trenched for the placing of the distributor piping.

After the distributor piping is in place and complete, the surface of the filtering material shall be brought accurately to the finished grade and lightly tamped around the distributor piping.

Trucking or carting over the surface of the filtering material after it is in place will not be permitted. If required to transport materials across the filtering material already in place, track and tight cars may be used with mechanical means for hauling the cars. Horses and other beasts of burden will not be permitted in hauling materials across the filtering material.

105. 8.—Disposal of Rejected Material.—The Contractor shall dispose of the fine and the coarse material removed by rescreening and all rejected material not taken away by the stone contractor within thirty (30) days, by placing it in spoil banks, by use in making roads and walks, or otherwise as directed.

If approved by the Director suitable material rejected by the coarse screen may be used for the layer of coarse material on the cover blocks.

105. 9.—Measurement.—Payment for placing filtering material under Item 105*a* shall be based on the actual total quantity passed through the rescreening plant as shown by the shipping weights determined by the Railroad.

Under Item 105*b*, payment shall be based on the total quantity placed in the filters as shown by the shipping weights determined by the Railroad.

105. 10.—Payment.—The unit price specified to be paid per ton for placing filtering material under Item 105*a* shall include the unloading from the cars, demurrage, if any, except as hereinbefore provided, transporting to the site of the work, storage for the convenience of the Contractor, rescreening, disposal of coarse and fine material removed by rescreening, and all rejected material not removed by the stone contractor within thirty (30) days and the placing and grading of the material in the filters, and shall include the furnishing and placing of all labor, tools, materials, equipment, and appurtenances necessary to do the work specified.

Under Item 105*b*, the unit price shall include all work specified under Item 105*a*, except rescreening and disposal of the material removed by rescreening.

The result of the bids received January 28, 1926, by the Director of Public Service were as follows:

1.—Bidder, The Botzum Brothers, Akron, Ohio.
Bid price, $1.50 per ton.
Quarry, The Dolomite Products Company, Narlo, Ohio.
Railroad facilities, Pennsylvania, Baltimore and Ohio, and Nickle Plate.

2.—Bidder, The W. E. Wright Company, Akron, Ohio.
Bid price, $1.85 per ton.

Quarries.	Location.	Railroad Facilities.
National Quarries Co.	Spore, Ohio.	T. & O. C. and B. & O.
Ohio Blue Limestone Co.	Marion, Ohio.	E. and B. & O.
Bluffton-Lewisburg Co.	Arlington, Ohio.	A. C. & Y. and B. & O.
Bluffton-Lewisburg Co.	Bluffton, Ohio.	A. C. & Y. and B. & O.
Wagner Quarries Co.	Sandusky, Ohio.	B. & O.

3.—Bidder, The Wagner Quarries Company, Sandusky, Ohio.
Bid price, $1.85 per ton.
Quarries, Plants 1, 3, 4, and 5, Sandusky.
Railroad facilities, Baltimore and Ohio Railroad.

4.—Bidder, The Bluffton-Lewisburg Stone Company, Findley, Ohio.
Bid price, $1.87 per ton.

Quarries.	Location.	Railroad Facilities.
Rimer No. 4.	Rimer, Ohio.	A. C. & Y. and B. & O.
Bluffton No. 1.	Bluffton, Ohio.	A. C. & Y. and B. & O.
Patterson Spur No. 5.	Arlington, Ohio.	A. C. & Y. and B. & O.

5.—Bidder, The France Stone Company, Toledo, Ohio.
Bid price, $1.90 per ton.

Quarries.	Location.	Railroad Facilities.
Bellevue	Bellevue, Ohio.	W. & L. E. and B. & O.
Bloomville	Bloomville, Ohio.	Penna. and B. & O.
Dunkirk	Dunkirk, Ohio.	Penna. and B. & O.
North Baltimore.	North Baltimore, Ohio.	B. & O.

6.—Bidder, The J. P. Loomis Coal and Supply Company, Akron, Ohio.
Bid price, $2.00 per ton.

Quarries.	Location.	Railroad Facilities.
Union	New Castle, Pa.	N. Y. C. and B. & O.
Lake Erie	New Castle, Pa.	P. W. & L. E. and B. & O.

The price bid by the general contractor for unloading and placing filtering material was $0.50 per ton. The general contractor also bid $0.70 per ton for "Rescreening and Placing Filtering Material," as called for by the specifications.

After the results of the tests of the quarry from which the stone was to be furnished the City of Akron were available, it was decided by the Engineers that the Contractor's rescreening plant would not be used.

The results of the inspection and tests of stone to be furnished in accordance with the proposals of the first four bidders is indicated on Table 2. From the test results, as well as on plant production capacity and facilities, the contract was awarded to the Wagner Quarries Company of Sandusky, Ohio, at its bid of $1.85 per ton. The freight rate from Sandusky to Botzum is 80 cents per ton, making the stone price, $1.05 per ton delivered f. o. b. cars, Botzum, Ohio.

Check tests on the filtering material in the spring of 1927 are indicated in Table 3.

In the first shipments some trouble was experienced in that the cars received contained a considerable quantity of fine material as well as dust. As a result of this experience, the quarry people installed a pneumatic dust-collecting system and also placed shaker screens in addition to the circular screening equipment. While the plant at the quarry was producing Akron

TABLE 2.—RESULTS OF LABORATORY TESTS AND QUARRY INSPECTION FROM QUARRY SAMPLES OF STONE FOR AKRON TRICKLING FILTERS IN ORDER TO DETERMINE LOWEST AND BEST BID, FEBRUARY, 1926.*

Items.	Dolomite Products Co.			National Quarries Co.		Ohio Blue Limestone Co.		Wagner Quarries Co.					
								Plant 1.		Plant 4.		Plant 5.	
	Top half (20 ft.)	Bottom half (20 ft.)	Mill sample.	Top half (15 ft.)	Bottom half (15 ft.)	Top half (12 ft.)	Bottom half (12 ft.)	Top half (9 ft.)	Bottom half (9 ft.)	Top half (7 ft.)	Bottom half (7 ft.)	Top half (30 ft.)	Bottom half (30 ft.)
Percentage of wear	5.2	5.7	5.4	3 3	5.2	3.0	5.6	3.3	3.2	3.0	3.0	5.0	3.8
Hardness.. Sample A	16.7	14.4	17.1	17.2	12.7	16.3	16.4	15.2	16.5	16.3	16.9	15.1	17.3
Hardness.. Sample B	14.3	16.8	14.7	17.0	16.3	16.3	11.0	16.4	16.2	16.9	16.9	13.9	13.0
Hardness.. Sample C	.....	10.2	.....	.....	.....	.....	14.4	.....	.....	.....	.....	.....	.....
Hardness.. Average	15.5	13.8	15.9	17.1	14.5	16.3	13.9	15.8	16.3	16.6	16.9	14.5	15.1
Toughness. Sample A	8	4	11	11	5	10	6	9	9	9	7	5	10
Toughness. Sample B	4	7	4	11	9	9	5	7	10	11	10	8	6
Toughness. Sample C	.....	4	.....	.....	.....	.....	6	.....	.....	.....	.....	.....	.....
Toughness. Average	6	5	7.5	11	7	9.5	5.7	8	9.5	10	8.5	6.5	8
Specific gravity	2.61	2.59	2.66	2.70	2.61	2.69	2.60	2.66	2 .68	2.64	2.67	2.40	2.62
Absorption, percentage	1.5	1.7	1.2	0.7	1.2	1.1	1.1	0.9	0.5	1.1	0.7	4.7	1.4
Soundness. Sample A, percentage of loss	0.0	0.0	0.0	1.44	2.85	2.8	0.24	0.18	0.0	0.0	0.0	0.0	0.74
Soundness. Sample B, percentage of loss	0.0	0.1	1.87	0.0	0.0	0.0	0.62	0.0	0.03	0.03	0.0	0.0	0.0
Soundness. Sample C, percentage of loss	.....	0.2	.....	.....	.....	.....	0.15	.....	.....	.....	.....	.....	.....
Thickness of ledges, in feet	0.25 to 6			0.3 to 5		0.3 to 4		0.7 to 4		0.7 to 3		0.7 to 6	
Plant capacity per 10-hour day, in tons	5 000			500		500		6 500		2 200		4 000	

*Compiled by A. S. Rea, Testing Engr., Ohio State Highway Dept.. and J. E. Root, M. Am. Soc. C. E.

specification stone in a quantity of approximately 2 000 tons daily, little or no trouble was experienced in receiving stone graded as per specifications. At times when the plant endeavored to furnish a quantity in excess of that specified additional fines would be produced and get into the carload shipments.

TABLE 3.

Items.	Akron specifications.	Average test results prior to contract award, 1926.	Wagner Quarries, Plant 1, Check Tests, 1927.				
			Stock Pile.				Quarry.
			No. 1.	No. 2.	No. 3.	No. 4.	
Hardness (not less than).....	14	16.1	16.4	15.7	16.0	16 8	16.0
Toughness " " "	5	8.8	7.5	8.0	8.5	8.5	8
Wear percentage (not more than).	6	3.25	3.8	4.0	3.4	3.7	4.9

In the beginning an attempt was made to sample and inspect the material when the loaded cars arrived at the Akron plant. This did not prove satisfactory as it delayed unloading the cars from 12 to 24 hours and, further, when a car was condemned it had accumulated approximately $55 freight charges and, should the unloading contractor start to unload a car prior to condemning it, there was no means whereby the remainder of the stone in the car could be kept from going on to the filter bed. As a result of this experience an inspector was placed at the quarry and with a set of screens and scales made constant inspections and observations with reference to the loading of the crushed material.

During the winter of 1926-27 the quarry produced Akron specification stone and stored it in stock piles. When shipments were resumed in the spring of 1927, Akron stone was taken from stock piles as well as from quarry production.

For a period of one year the City retained one of its Assistant Engineers as inspector at the quarry and during about five months of the entire producing period had an additional assistant there. The total inspection cost was approximately $4 000.

In all, approximately 2 469 cars were sampled and inspected out of a total of 4 236 cars. The total weight represented by the inspected cars was 147 854 tons and the total quantity of stone delivered and unloaded at the Akron plant, 259 770 tons. The results of the tests made are indicated in Table 4.

The results of the Akron experience, after all shipments of stone had been received, indicates that the rescreening plant called for in the specifications to be operated by the general contractor would have produced no appreciable results, and the decision to omit this rescreening plant is felt to have been wise.

In the preparation of a new specification for furnishing filtering material of a size from 1 in. to 2½ in., it is felt that the only practical means of pre-

venting fine material from getting into carload shipments, will be the requirement of a complete rescreening of the material by the material contractor and at the place of production. This rescreening at the place of production can be done at a very nominal cost and with not much inconvenience to the stone producer.

It is expected to operate the Akron trickling filters continuously during the entire year.

TABLE 4.

Samples.	Number of cars sampled.	Total weight, in pounds.	Retained on 2½-inch screen, in pounds.	Percentage.	Passing 1-inch screen, in pounds.	Percentage.
Sampled on job	63	8 283 000	308 150	3.7	361 370	4.4
" at quarry, 1926	416	53 270 600	1 705 740	3.2	1 289 490	2 4
" " " ,1927	1 990	234 154 400	1 503 545	0.6	3 670 700	1.6
Total for all cars sampled	2 469	295 708 000	3 517 435	1.2	5 321 560	1.8

Baltimore, Md.—The following excerpt is quoted from the specifications by Milton J. Ruark, Sewerage Engineer:

"Broken Stone Filtering Material

"The filtering material shall consist of crushed or broken stone of hard material which will not disintegrate. No stone which shows the slightest signs of disintegration, no gneiss carrying appreciable amounts of coarse-grained pegmatite or vein matter of quartz feldspar, no soft limestones, soft sandstones, shales or schists will be allowed to be used. The filtering material shall be composed of a stone which breaks or crushes in approximate cubes, or in pieces which are approximately equi-dimensional. The presence of more than ten (10) per cent. of flag pieces or slabs will be deemed sufficient cause for the rejection of an entire lot of broken stone. Any piece of stone will be considered a slab which has two approximately parallel faces, the average of whose areas is more than five (5) times the distance between the approximately parallel faces.

"The filtering material shall not contain dirt, dust, clay, sand, or other foreign matter, and when shaken with clear water shall leave the water substantially clean and clear. The method of obtaining filtering material free from dirt, dust, clay, sand, or other foreign matter will be left to the Contractor, but material failing to meet the above requirements will be subject to rejection."

Mr. Ruark states that, in deciding upon the acceptability of the material:

"Mr. Ezra B. Whitman, the Engineer in charge of the design and construction of the trickling filters, along with Professor Edward B. Mathews, State Geologist, made an inspection of the quarries from which it was proposed to obtain the stone.

"There was no difficulty in obtaining a uniform product.

"The source of supply as indicated above, was inspected before the work was done. After that the inspection was carried on at the sewage plant.

"Since the filtering material was of unusually good stone, chemical and physical tests were not considered necessary.

"The chief difficulty in getting a suitable filtering material consisted of having it free from fine dust and broken stone. In order to accomplish this the stone was washed immediately before it was loaded into barges.

"The Engineer naturally was the one who decided the source of supply and the quality of the material."

The filters at Baltimore were started in 1911 and operate during the entire year.

Canton, Ohio.—The following excerpts are quoted from the communication from Mr. George A. Reese, of McClasky and Reese, Consulting Engineers:

"In the construction of this plant, about 80 500 cu. yd. of filtering material were required for the trickling filter units. To those familiar with sewage treatment work, it is known that one of the most costly single items incorporated in the treatment plant, because of the volume necessary, is the filtering medium. In order to give the city every benefit of economy on this item without sacrificing the effectiveness of any readily accessible and suitable material, proposals were asked for hard, crushed lime rock, crushed trap rock, crushed blast furnace slag, and crushed boulders, although it was doubtful if the latter material could be expeditiously produced in such volume.

"The specifications required that the material should be composed of sound, hard, durable particles which would not disintegrate and which should be free of dust, dirt, clay, screenings, chips, or other foreign and undesirable matter. Samples shaken in water were to leave the water substantially clean and clear. The bidder was required to state the location of the source of supply of the material upon which he bid. The bottom layer, about 6 in. in thickness, was to consist of stones 3 to 4 in. in size while the remainder was to be from 1½ to 2¾ in. in size. It was required that the material be re-screened immediately upon unloading and prior to placing. Customary stipulations were included with reference to placing the material, regarding protection of the floor system, proper placing of stone over the floor blocks, keeping the floor channels free of chips, spalls, or other foreign matter, protection of the structures, cleanliness of material during the placing and subsequent thereto, providing proper bearing for the distribution pipes, etc. Samples of proposed materials were to be submitted in sufficient quantity and sufficient time for thorough examination before approval of their use, and all material was to be equal in all respects to the approved specimen.

"In order to maintain the required quality of the material before permission to unload was given, each carload was systematically inspected for general characteristics, size, cleanliness, hardness, and other relevant features, and also compared with the approved sample. Periodical physical and chemical tests were made from samples taken at random, both at the source of supply and point of delivery, and carried out to sufficient degree to cover the salient requirements.

"One of the principal factors in determining upon the use of crushed blast furnace slag was the excellent condition of the slag in the contact beds which the trickling filters were supplanting. This existing material was removed to place the trickling filter floor system and because of its small initial size (½ to 1½ in.). This material was in service for ten years and showed no indications of cementation, disintegration, or breaking down to any appreciable extent. This satisfactory condition was found at numerous test pits in the old beds and later substantiated by further careful examination when the entire material was removed. Apparently, had this material been of larger size, it could have been used in the trickling filters, after being cleaned of sewage matters which had collected from greatly over-worked sedimentation tanks. Another deciding factor was the benefit of lower price. However, it was left to the judgment and decision of the Engineer for final selection. Chemical

and physical properties, uniformity of product, a better product than in the past because of more stringent stipulations required by the slag producers of the blast furnaces, inspection of source of supply, proximity of source of supply, and ability to produce the material in quantities for required progress were other deciding factors, named substantially in order of their relative given weight.

"These filters were first put into operation in 1926, and were operated for a portion of the winter of 1926-1927. It is the intention to run these units during the entire year."

Cleveland, Ohio.—George B. Gascoigne, M. Am. Soc. C. E., makes the following statement in regard to the Cleveland plant.

The Southerly Sewage Treatment Works at Cleveland, Ohio, includes six units of trickling filters each 1 acre in area and 10 ft. in depth. There was placed in the filters 97 681 cu. yd. of material which weighed by actual car weights, 2 400 lb. per yd. The filters will not be operated during high flows in the Cuyahoga River.

After carefully considering the procedures that have been followed in the past, after actually selecting a material which was thought by a number of competent engineers to be one of the best materials for trickling filter purposes and which, on use, showed some disintegration, and after inspecting and testing the stone from some twenty different limestone quarries in Northern Ohio, it was decided that the most practical procedure to follow in obtaining a suitable material for the Cleveland filters was by comparison with a satisfactory material in service. Consequently, the specifications provided:

"In general, the filtering material shall consist of approximately nine (9) feet of broken limestone covered with one (1) foot of trap rock. Under the floor block of the trickling filters and to a depth of about six (6) inches, a bottom layer of broken limestone shall be placed by hand.

"The broken limestone for the trickling filters shall be sound, hard limestone rock, free from seams and porous spots and equal in all respects to the sample of stone on display in the offices of the Commissioner and the Engineer duly identified for the intended purpose.

"The trap rock for the trickling filters shall be a fine grained basic and volcanic rock having a closely interlaced mineral structure, free from seams, faults, and iron in the low oxide form. Also, it shall be equal in all respects to the sample on display in the offices of the Commissioner and Engineer duly identified for the intended purpose."

The first step in selecting the limestone and trap-rock materials was to have the Contractor request the approval of materials from some specific quarries, obviously situated within a reasonable shipping distance of Cleveland. These quarries were then visited to determine whether or not adequate facilities for quantity production, proper sizing, and cleanliness were available. Furthermore, the quarries were carefully inspected to ascertain the nature of the material with particular reference to variations of structure and, in the different strata, cleanliness of bedding planes, presence of chert and shale, and the appearance of quarried material subjected to long exposure.

Samples representative of the different types of material found in the quarry were secured and, after inspecting the quarry face and stock piles, an estimate was made, with the assistance of the quarry superintendent, of the amount of each variety likely to appear in the finished product of the size

designated. The product of the quarry under consideration was then compared with the product on display as to general appearance, uniformity, and results of tests, principally for soundness, using the sodium sulfate test in practically the same manner as given in *Bulletin 1216* of the U. S. Department of Agriculture.

The final choice was given to the material which, where conditions as to suitability and adequate production were complied with, was most uniform in structure at the source and in other respects compared with the characteristics of the sample on display, the greatest stress being laid on the soundness. The sample on display was a selected material which had remained unchanged after one year of continuous service in a trickling filter subjected to rather severe weather conditions.

Columbus, Ohio.—Clarence B. Hoover, M. Am. Soc. C. E., Superintendent of the Division of Water and Sewage, quotes the contract specifications in part, as follows:

"The filtering material shall consist of crushed or broken stone, free from splinters or flat pieces and shall be of hard material which will not disintegrate. If limestone is used only the hard grades will be accepted. The filtering material shall be equal in all respects to samples on file in the office of the Engineer.

"The filtering material shall be screened into two (2) sizes, as follows:

"No. 1 shall be of such size as to all pass through a screen having a clear mesh of four (4) inches and be retained on a screen having a clear mesh of two and one-half (2½) inches.

"No. 2 shall be of such size as to all pass through a screen having a clear mesh of two (2) inches and be retained on a screen having a clear mesh of one-half (½) inch.

"In each case the material shall be graded in size between the maximum and minimum limits specified. The filtering material shall not contain any dirt, dust, clay, or sand, and when shaken with clean water shall leave the water substantially clean and clear. The method of obtaining filtering material free from dirt, dust, clay, or sand, will be left to the Contractor, but material failing to meet the above requirements will not be accepted and shall not be loaded and transported to the site of the work.

"Especial care shall be taken in transporting and placing the filtering material to keep it clean. Any material which may have become dirty, either before or after it has been placed in the filters, shall be either removed and cleaned, or replaced with clean material in a satisfactory manner. The No. 1 material shall be placed to a uniform depth of ten (10) inches above the concrete floor and on it shall be placed the No. 2 material with its surface level and at the proper elevation. Especial care shall be taken in placing the filtering material not to damage the lateral collectors or the cast-iron risers. Any work which is damaged shall be replaced in a satisfactory manner by the Contractor at his own expense."

Mr. Hoover further states:

"The material as delivered on the job was tested principally to find out whether or not it met the physical requirements of the specifications, *i. e.*, with respect to freedom from dirt, and other fine particles, size, and uniformity.

"The filtering material consists of broken stone having a total average depth of about 5 ft. 4 in., the lower 10 in. being from 3 to 4 in. in size. In Filters Nos. 1 and 2 the material above the lower course has a nominal size of from 1½ to 3 in. The material was sampled carefully from time to time and mechanical analyses were made from which it was found that the

effective size was 1.4 in. and the uniformity coefficient, 1.4 in., and that the average size of the stone was 1.7 in., that being the diameter of a sphere of equal volume. In Filters Nos. 3 and 4 the material has a nominal size of from 1 in. to 3 in., an effective size of 1.1 in., a uniformity coefficient of 1.6 in., and an average size of 1.5 in. The material is all limestone, obtained partly from quarries near Columbus and partly from Marion, Ohio, and was screened at the quarries to remove the dust and fine particles and to obtain material of the right size.

"During the past ten years the filters have been operated between April 1 and January 1, and have not been operated during the balance of the year."

These filters were placed in operation in November, 1908.

Decatur, Ill.—The reply from William E. Stanley, M. Am. Soc. C. E., relative to this plant is as follows:

"Ample supplies of limestone were available within reasonable distances as sources of materials for the filter media. However, there was some indication that not all of the limestone quarries could furnish stone which would stand up in service. Investigation disclosed that no real methods of selecting or testing had been developed by which the probable durability of a given material for use in a sewage filter could be predetermined.

"This lack of knowledge as to tests and methods for selection of the filtering material made it necessary to select the material more on a price basis than should be done for so important a unit in the treatment plant."

The specifications are quoted in part, as follows:

"The broken stone for the sprinkling filters shall be sound, hard limestone rock, free from seams and porous spots, satisfactory in all respects to the Engineer. The limestone shall be broken to such sizes as will be retained on a screen having circular holes one (1) inch in diameter, and will pass through a screen having circular holes two (2) inches in diameter. The stone shall be from a quarry where the limestone crushes in pieces with all three diametral axes as nearly the same length as practicable.

"Pieces of one (1) to two (2) inch stone having a single dimension longer than three (3) inches shall be removed. The bottom of the filter shall be brought to a horizontal surface with stone screened between two and one-half ($2\frac{1}{2}$) and four and three-quarters ($4\frac{3}{4}$) inches in diameter as described above, placed in a layer with minimum thickness of six (6) inches.

"All stone shall be clean and free from dust, screenings, fine stone, dirt, or other foreign substances, and shall be thoroughly washed before being placed in the filters. When the washed stone is shaken with clean water in a suitable vessel, the water shall remain substantially clear and clean. If necessary, the stone shall be rescreened, before placing in the filters."

The following comments pertain to the selection of material:

"It will be noted that these specifications are very general with reference to physical qualities and provide no special tests for the determination of the suitability of the filtering material. The Engineers were able to exercise a considerable influence in the selection of the quarry from which the material was obtained and the final selection was based on a careful study of the proposed material and the experience with similar stone in operation. Thus, the selection of material was determined first by cost considerations and, second, by quality considerations. There were several quarries from which the material could be obtained at practically the same cost so the final selection was determined largely by the character of stone in the quarry and the facilities at the quarry for getting out material of the proper size and freedom from objectionable substances such as dust and dirt.

"Before giving approval as to the quarry from which the material was to be obtained the Engineers made a careful study of a number of quarries. These included quarries proposed by the Contractor as quarries where he could get material in proper quantity and at a satisfactory price. The study included an inspection of the quarry to determine the uniformity of the rock strata, facilities for producing material of the size desired, facilities available for and care taken to obtain clean stone free from dirt, screenings, and dust.

"Samples of the crushed stone were obtained from the various quarries and chemical analysis obtained; also information was obtained as to the physical properties of the stone, including specific gravity, absorption, and resistance to wear.

"The chemical analysis of the stone from several quarries was compared to the chemical analysis of stone from a number of filters such as Madison, Wis., the Calumet Plant, in Chicago, and a number of others where limestone had been in service for a number of years.

"The chemical and physical tests were made by a commercial testing laboratory. The chemical analysis included a determination of the principal constituents (silica, iron, and alumina, calcium carbonate, and magnesium carbonate), which made up 99.4 to 99.9 per cent. of the mineral contents of the stone.

"The trickling filters in connection with the Decatur Sewage Treatment Works include three (3) acres of crushed limestone having an average depth of six and one-half (6½) feet.

"The filter units were put into operation in 1924 and have been in service since. The operation is continuous through the winter as well as the summer except for short periods when the filters have been out of service because of excessive high water in the Sangamon River."

Lincoln, Nebr.—Owing to the absence of H. P. Letton, M. Am. Soc. C. E., the Committee's inquiry was not received in time to obtain his direct reply. However, the following information is obtained from his report on an investigation of stone for sprinkling filters. This probably is one of the first instances where comparative tests were made to determine the suitability of a material for filtering media.

Samples of limestone from various local and near-by quarries, a sample of gravel, and a sample of quartzite, were submitted to alternate freezing and thawing. In order to approximate somewhat the conditions to which the stone would be subjected in the filter, it was decided to place the samples of various stones and gravel, which had been thoroughly soaked in water, in a room in a cold storage house in which a temperature of about 8° Fahr. was maintained. The stone was taken out from the cold room almost every morning, was thawed out with warm water, then cooled down with cold water, and placed back in the cold room. Photographs of the stone tested were taken prior to commencing the test, and photographs of the same material were taken after the test was completed. The samples were alternately frozen and thawed thirty-four times.

As a result of these tests it was found that the limestone and gravel, with the possible exception of a portion of one quarry, disintegrated to such an extent that the conclusion was reached that they would prove unsatisfactory for trickling filters. The quartzite was unaffected. Observations on filters where similar materials were in service confirmed the findings in the tests. After carefully weighing all the factors involved, it was decided to use the

quartzite which, notwithstanding a somewhat larger initial cost, was deemed the most suitable and ultimately the most economic.

Reading, Pa.—The following excerpts are taken from a communication from E. Sherman Chase, M. Am. Soc. C. E., who served as Resident Engineer during the building of three of the four 1-acre filter units at Reading, Pa., and who operated the plant for about three years. A copy of the specifications for the filtering material was not available:

"In the case of the first and third filters, the material was blast furnace slag from an old dump which had been weathering for a good many years. The material was quarried from the dump, put through a crusher and rotary screen, loaded on to railroad cars and transported about 2 miles to a siding three-quarters of a mile from the filters. At this siding the material was dumped upon a platform from whence it was forked into wagons and then hauled to the filter.

"In none of the filters was the material as uniform in size as is desirable, although in my opinion it was distinctly better in the case of the third unit than in the case of the first. In the first unit the size of the slag was expected to run from 1½ to 4 inches. As a matter of fact, it ran from ½ to 6 inches and numerous pockets of fine material occurred which gave more or less trouble due to clogging. In the case of the third unit built, the slag ran from 1½ to 4 inches, and was reasonably free from pockets of fine material.

"In the case of the second unit built, the material was a sort of feldspar obtained from a quarry about a mile distant from the filters. This material was not very satisfactory due to the fact that it broke along flat cleavage planes and also to the fact that a great deal of it disintegrated, forming a sort of clay which tended to clog the filter beds.

"Generally speaking, the criterion upon which the adoption of the filter material at Reading was based, was the cost with which it could be procured and transported.

"In all cases there was a certain amount of inspection at the source of supply, but no chemical or physical tests. Selection was based somewhat upon the judgment of the Engineer.

"While there, I made some tests of the media and found that the specific gravity of the slag approximated 2.2 and that of the feldspar about 2.6.

"The following table gives some data relative to the shape of the individual pieces:

"RATIO OF AXES OF FILTER MEDIA, READING, PA.

Material.	Maximum.	Medium.	Minimum.
Stone	2.5	1.5	1
Slag	2.0	1.4	1

"I also made some measurements of the size of the filter material with the following results:

"SIZE OF FILTER MATERIAL AT READING, PA.
(Size, in terms of diameter of equivalent spheres, in inches.)

Material.	Average.	90% by weight less than:	10% by weight less than:
Stone (run)	2.1	2.9	1.6
Slag (top)	1.6	2.1	1.3
Stone (top)	1.5	2.9	1.3

"In considering the use of these materials at Reading, it should be noted that the first unit of filters was the first municipal trickling filter to go into operation in the United States and that the other two units followed within a few years. At that time experience in this country with trickling filter media was very limited.

"These filters were operated the year around and so far as I could observe comparatively little disintegration was caused by frost action. The feldspar appeared to disintegrate upon exposure to the air, irrespective of temperature conditions."

Worcester, Mass.—The following reply was received in regard to the Worcester plant:

"In selecting the materials for the trickling filters of the sewage disposal plant of the City of Worcester, Mass., the Engineers were fortunate in having a ledge of good hard granite located on property adjoining the old disposal plant.

"This was purchased and a complete crushing and screening plant erected together with the necessary bins and tracks.

"125 000 tons were used from this plant. Later, to expedite the work, 175 000 tons of trap rock were purchased.

"The specifications called for hard trap rock, broken to sizes that would pass a 3-inch screen and be caught on a 1-inch screen and to be screened clean.

"Both the material from our own ledge and that bought outside, was constantly inspected and tested for quality, size, and clean screening.

"In selecting the material purchased, the quality as shown by tests, uniformity of the product, availability as to distance, and price, were the important factors in the order named.

"The granite was hard and of good quality, typical of the usual granite of this vicinity. The trap rock was from the famous trap-rock belt of New England and came from a quarry that ran very uniform and proved entirely satisfactory."

It should be stated that the work at Worcester was done by day labor under the direction of the City Engineer, Ralph G. Lingley. The plant was placed in operation in 1925 and operates the year around.

APPENDIX II

Suggested Tentative Methods of Sampling Materials for Use as Trickling Filter Medium*

By George B. Gascoigne,† M. Am. Soc. C. E.

Samples of all materials for test on which is to be based the acceptance or rejection of the supply shall be taken by the Engineer or his authorized representative at the source of supply, and after a thorough inspection. Samples from proposed sources or for preliminary test may be submitted by a producer or owner of the supply.

* Am. Soc. for Testing Materials, Standard Method, Serial Designation D 75–22, Modified.

† Cons. San. Engr., Cleveland, Ohio.

Sampling of Stone from Quarries for Quality and Size

Basic Data.—

Location of quarry,
How long worked,
Name of owner,
Kind of stone,
Amount and character of overburden or shipping,
Depth of quarry face,
Length of quarry face,
Approximate quantity of unquarried stone available,
Location of proposed workings during period for which material is to be used,
Equipment for crushing,
Equipment for screening, including size and shape of screen openings, length of screen sections, angle of screen with the horizontal, the speed of screen rotation, and the rate at which the screen is fed.

Inspection.—The ledge or quarry face shall be inspected closely to determine any variations in different layers. Any difference in color or structure shall be observed, and the relative amounts of each variety occurring in the entire face shall be estimated and shown on a sketch, particular emphasis being given to that portion of the quarry from which the proposed material is to be taken. Observations as to the occurrence of chert, fossils, shale, seams, or materials foreign to the material under consideration, should be carefully made and recorded. The effect of weathering on exposed faces should also be noted.

Furthermore, the facilities for crushing, screening, sizing, storing, and shipping material should be examined. A representative of the quarry should accompany the Engineer making the inspection.

Sampling.—The samples should be taken from two sources, namely, from that portion of the face of the quarry representing the proposed workings, and from the storage pile or loading bin containing the same material of sizes as near as possible to those for the intended use.

For the standard stone test, separate samples, at least 30 lb. of fresh unweathered specimens in each, shall be taken from all layers that appear to vary in color or structure. When more than one piece is taken, the minimum size shall be 2 in. except that there shall be one piece of each sample to be used in the toughness or compression test, which shall have a minimum size of 4 by 5 by 3 in. on which the bedding plane shall be marked and which shall be free from seams or fractures.

A sample of crushed and screened material ready for shipment and weighing at least 80 lb. shall also be taken, preferably from cars or boats while loading from stock piles or bins. In order that the sample may be representative, it is recommended that separate samples be taken at different times while the material is being loaded. If the sample must be taken from the bin or stock pile, several samples shall be taken from different parts of the stock pile and from the top of the bin, and the loading chute. These separate samples shall be well mixed to form a composite sample, and the sample for testing shall be obtained by the quartering method.

If it is not practicable to visit the plant, samples for both quality and size shall be taken from different parts of the car or boat during unloading. It is recommended that separate samples be taken from the top, middle, and bottom of the car or boat. These separate samples shall be well mixed to form a composite sample, and the sample for testing shall be obtained by the quartering method. This method should only be used to check the quality of a stone previously sampled at the source. In this way the general quality of the stone can be compared with the original quarry sample, and check tests on various shipments would indicate any change in quality. In this case, tests for both quality and size can be made on the same sample.

The sample of crushed stone, if collected for mechanical analyses only, shall weigh at least fifty times the weight of the largest piece therein.

Slag.—It is recommended that blast furnace slag be sampled for size and quality by the same general methods specified for stone.

General.—In sampling materials or inspecting the sources of supply of material for trickling filter media, experience and skill are necessary to attain the desired degree of accuracy. It is obvious that precautions as to variations must be observed closely, particularly in those sources where portions are known to be unsuitable, while in other sources where the material is uniform and of recognized sound structure, such as certain trap rocks, there can be a certain relaxation. However, no matter what the source or kind of material, due care should be given to follow the procedures mentioned so that no doubt can arise as to the sample fairly and truly representing the material to be furnished.

APPENDIX III

Suggested Tentative Tests to Determine Suitability of Filtering Material

By George B. Gascoigne,* M. Am. Soc. C. E.

Regular Procedure

In order to determine the suitability of a material for trickling filter media the following laboratory tests are suggested to be applied in all cases if possible:

Apparent Specific Gravity;
Absorption;
Percentage of Wear;
Toughness;
Soundness; and,
Chemical Analysis.

Since the methods of making these tests, with the possible exception of that for soundness, are relatively well established, there seems to be no reason why they should not be followed.

* Cons. San. Engr., Cleveland, Ohio.

Specific Gravity and Absorption.—The following method is taken from the U. S. Department of Agriculture, *Bulletin No. 1216,* entitled, "Tentative Standard Methods of Sampling and Testing Highway Materials":

Tests for Apparent Specific Gravity and Absorption of Stone or Other Coarse Materials

(1) The apparent specific gravity shall be obtained by weighing the water displaced by a sample of the material weighing approximately 1 000 grammes, broken into pieces about 1¼ in. in diameter. The vessel to be used consists of a galvanized-iron cylinder closed at one end and measuring 5 in. in diameter by 8 in. high. A brass spout ½ in. in diameter is soldered into the side of the cylinder 6 in. from the bottom. The spout is inclined at an angle of 2° with the horizontal and is 2½ in. long. A notch is filed across its lower end to stop the drip from the displaced water. To determine the specific gravity and absorption, the dried and cooled sample shall be weighed to the nearest 0.5 gramme and immersed in water for 24 hours. The pieces shall then be surface-dried individually with a towel, the sample re-weighed, and immediately placed in the cylinder, which has been previously filled to overflowing with water at room temperature.

(2) The weight of water displaced by the sample shall be used to calculate its apparent specific gravity. The difference between the original weight of the sample and its weight after 24 hours shall be used to determine the absorption.

Abrasion.—

Abrasion Test for Broken Stone
(A. S. T. M. Standard Method, Serial Designation D2-08, Slightly Modified.)

(1) The machine shall consist of one or more hollow iron cylinders, closed at one end and furnished with a tightly fitting iron cover at the other; the cylinders to be 20 cm. in diameter and 34 cm. in depth inside. These cylinders are to be mounted on a shaft at an angle of 30° with the axis of rotation of the shaft.

(2) The rock to be tested shall be broken from large pieces to as nearly uniform size and shape as possible, and as near to fifty pieces as possible shall constitute a test sample. No pieces with edges or faces that have been rounded by wear shall be included. The total weight of rock in a test shall be within 10 grammes of 5 kg. All test pieces shall be washed and thoroughly dried before weighing. Ten thousand revolutions, at the rate of between 30 and 33 per min., shall constitute a test. Only the percentage of material worn off which will pass through a 0.16 cm. (1/16-in.) mesh sieve shall be considered in determining the amount of wear. This shall be expressed as the percentage of the 5 kg. used in the test.

(3) When the material has a specific gravity below 2.20, the quantity used for the test shall be adjusted on a weight basis, retaining the specified number of pieces. For such materials a weight of 4 000 grammes of the broken stone or broken slag shall be used.

(4) The results shall be reported as percentage of wear.

Toughness.—

Standard Method of Test for Toughness of Rock
(Serial Designation D3-18.)

This method is issued under the fixed Designation D3. The final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision. This method, adopted in 1908, and revised in 1918,

was approved March 28, 1921, as "Tentative American Standard" by the American Engineering Standards Committee.

(1) Toughness, as applied to rock, is the resistance offered to fracture under impact, expressed as the final height of blow required of a standard hammer to cause fracture of a cylindrical test specimen of given dimensions.

(2) Any form of impact machine which will comply with the following essentials may be used in making the test:

(*a*) A cast-iron anvil weighing not less than 50 kg., firmly fixed on a solid foundation.

(*b*) A hammer weighing 2 kg., arranged so as to fall freely between suitable guides.

(*c*) A plunger made of hardened steel and weighing 1 kg., arranged to slide freely in a vertical direction in a sleeve, the lower end of the plunger being spherical in shape, with a radius of 1 cm.

(*d*) Means for raising the hammer and for dropping it upon the plunger from any specified height from 1 to not less than 75 cm., and means for determining the height of fall to approximately 1 mm.

(*e*) Means for holding the cylindrical test specimen securely on the anvil without rigid lateral support, and under the plunger in such a way that throughout the test the center of its upper surface shall be tangent to the spherical end of the plunger at its lowest point.

(3) Quarry samples of rock from which test specimens are to be prepared shall measure at least 6 in. on a side and at least 4 in. in thickness, and when possible shall have the plane of structural weakness of the rock plainly marked thereon. Samples should be taken from freshly quarried material, and only from pieces which show no evidences of incipient fracture due to blasting or other causes. The samples should preferably be split from large pieces by the use of plugs and feathers and not by sledging. Commercial stone-block samples from which test specimens are to be prepared shall measure at least 3 in. on each side.

(4) Specimens for test shall be cylinders prepared as described in Section 5, 25 mm. in height and 24 to 25 mm. in diameter. Three test specimens shall constitute a test set. The ends of the specimen shall be plane surfaces at right angles to the axis of the cylinder.

(5) One set of specimens shall be drilled perpendicular and another parallel to the plane of structural weakness of the rock, if such plane is apparent. If a plane of structural weakness is not apparent, one set of specimens shall be drilled at random. Specimens shall be drilled in a manner which will not subject the material to undue stresses and which will insure the specified dimensions.* The ends of the cylinders may be sawed by means of a band or diamond saw,† or in any other way which will not induce incipient fracture, but shall not be chipped or broken off with a hammer. After sawing, the ends of the specimens shall be ground plane with water and carborundum or emery on a cast-iron lap until the cylinders are 25 mm. in length.

(6) The test shall consist of a 1-cm. fall of the hammer for the first blow, a 2-cm. fall for the second blow, and an increase of 1-cm. fall for each succeeding blow, until failure of the test specimen occurs.

(7) The height of the blow, in centimeters, at failure shall be the toughness of the test specimen. The individual and the average toughness of three test specimens shall be reported when no plane of structural weakness is apparent. In cases where a plane of structural weakness is apparent, the indi-

* The form of diamond drill described in *Bulletin No. 347*, U. S. Department of Agriculture, pp. 6–7, is recommended, and should prove satisfactory if the instructions are strictly followed.

† A satisfactory form of diamond saw is described in *Bulletin No. 347*, U. S. Department of Agriculture, pp. 7–9.

vidual and average toughness of the three specimens in each set shall be reported and identified. Any peculiar condition of a test specimen which might affect the result, such as the presence of seams, fissures, etc., shall be noted and recorded with the test result.

Soundness.—By soundness of a filtering material is meant its ability to withstand the conditions of service without undergoing disintegration or splitting up into small pieces.

Immerse not less than eight pieces of the material of the same size to be used on the work (total weight, not less than 1 000 grammes) in a saturated solution of sodium sulfate at 70° Fahr., contained in an agate-ware or other suitable container (preferably with cover) of adequate capacity. Crystals of the sodium sulfate should be present in the dish to assure a saturated solution. After 20 hours immersion remove the pieces from the solution and dry for 4 hours in a drying oven maintained at 100° cent. After drying, remove from the oven, examine quickly, and immediately re-immerse in the sodium sulfate solution. One immersion and one drying constitutes a cycle. Repeat this treatment for 20 cycles, or until failure.

All pieces should be examined at the end of each cycle and the condition recorded.

If a piece of material which exhibits disintegration, marked checking, or cracking, or is split into three or more separate pieces, or is so cracked that it is evident that it will do so, shall be considered to have failed in this test.

Chemical Analyses.—For the chemical analyses, the following determinations should be made: Insoluble matter; iron oxide and alumina; calcium; magnesium, and sulfur. The methods suggested for these analyses are those by Mr. W. F. Hillebrand.* For limestones, the Tentative Methods for Chemical Analysis of Limestone, under Serial Designation C25-26T, of the American Society for Testing Materials, is suggested.

The importance of the chemical analysis does not appear to be fully established. However, certain determinations ultimately may shed some light on the behavior as to disintegration or disruption in some instances. This may require a separation of the iron and alumina, and a determination of the condition of the sulfur in the original sample. Furthermore, more rapid methods for calcium and magnesium are being proposed which, when developed, may prove satisfactory and will result in much saving of time.

Other Tests.—In the study of any particular material any information gained is valuable and while it may not be essential to include all tests in routine procedure, the following tests in addition to those mentioned may be considered:

True Specific Gravity;
Porosity;
Hardness (Dorry Machine);
Actual Freezing and Thawing Tests; and
Mico-Structural Analysis.

Where such tests are used they should be made in accordance with recognized practice.

* "Analyses of Silicate and Carbonate Rocks."

APPENDIX IV

SANITARY ENGINEERING DIVISION AMERICAN SOCIETY OF CIVIL ENGINEERS COMMITTEE ON FILTER MATERIALS FOR SEWAGE AND WATER-WORKS

Data Desired from State Sanitary Engineers Regarding Filter Materials for Sand Sewage Filters

The Committee of the American Society of Civil Engineers on Filter Materials for Sewage and Water-Works, desires to obtain detailed data of all sewage disposal plants using fine-grained filter materials in intermittent sand filters. To this end, it is desired that an answer to the following questions be sent to Mr. N. T. Veatch, Jr., c/o Black & Veatch, Mutual Building, Kansas City, Mo.

This list of questions is sent to you, hoping that you can reply to them without any serious trouble or inconvenience. The Committee realizes that it will take some time to get complete answers to the detailed questionnaire covering individual plants, a sample of which is attached, but it is anxious to have a reply to the questions directed to you as soon as convenient.

(1) Number of plants and location.....

(2) Have troubles been experienced in your State? If so, what were they?
.....

(3) What grading of filter material do you require?.....
.....

(4) What plants in your State have regular attendance?.....
.....

(5) Has any experimental work been carried on in your State covering the selection of fine-grained materials?.....
.....

(6) If so, where?.....

(7) Are there any data, published or otherwise, that are available covering these investigations?.....

(8) If so, where?.....

(9) Will it be possible for you to have the detailed questionnaires followed up by your office, both by correspondence and by personal visits, the latter to be in the regular course of your work?.....
.....

(10) Have you any suggestions to offer as to the best means of stimulating the interest of local authorities in the work of this Committee, with the end in view of getting the necessary data in as complete and accurate form as possible? .....
.....

As soon as this list of plants is received by Mr. Veatch, he will mail a sufficient number of information blanks as indicated by the attached form, so that the detailed data for the various plants can be furnished. It is suggested that these blanks be filled out as completely as possible, either from the

records in your file or by the Engineers who designed the plant. After all the data are collected, it is suggested that the plants be visited by some one to check up on the data given and add such additional information and comments as may develop from the inspection trip. As soon as the blanks are filled out to your satisfaction they can then be mailed to Mr. Veatch for compilation, along with the data obtained from the other States.

APPENDIX V

Notes Covering Experimental Work on Filter Sand for Water-Work

(1) *Copy of Letter Sent to Various Cities Requesting Co-Operation in Making Tests on Filter Sand.*—

"Lake Montebello, Hillen Road,
Baltimore, Md.,
December 12, 1927.

"Gentlemen.—The Committee on Filtering Materials of the American Society of Civil Engineers is endeavoring to secure the co-operation of a number of filter operators in running a series of experiments for determining the proper size and depth of filter sand.

"I am sending you herewith a copy of a drawing [Fig. 1] and letter, which we are sending to those whom we hope to have co-operate with us. I believe the entire cost of installation of a battery of small filters can be made for less than $100.

"We should be pleased to have you build one of these small plants and conduct the necessary experiments. We should also appreciate hearing from you at an early date as to whether you will undertake the work, as we wish to make a report to the Committee of the American Society of Civil Engineers before the January meeting.

"Very truly yours,
"James W. Armstrong,
"Member of Committee."

AMERICAN SOCIETY OF CIVIL ENGINEERS, SANITARY ENGINEERING DIVISION, COMMITTEE ON FILTERING MATERIALS

Small Experimental Glass Filters

At a recent meeting of the Committee on Filtering Materials of the Sanitary Engineering Division of the American Society of Civil Engineers, it was decided to conduct a number of experiments to determine, if possible, the optimum size, depth, and grading of filters, and ask the co-operation of filter men in different parts of the country.

Before deciding to undertake the conducting of these experiments, a questionnaire was sent to all the State Sanitary Engineers in an effort to learn the practice throughout the United States and the reasons for fixing upon any definite size and grading of sand. The answers received seemed to indicate that sand was selected as a matter of custom and that very little real

knowledge was apparently possessed by any one as to proper requirements for filter sand.

It is thought that the selection of filter sand for any given locality should be studied with reference to the character of water to be filtered, and the same careful consideration should be given to the selection of sand as is given to secure the proper chemical treatment of the water. For instance, the highly colored but fairly soft waters of New England, the waters of high organic content, such as are found in the Great Lakes and large impounding reservoirs, and the flashy and at times highly turbid waters of the Middle West, might each require for best results, sand of a different size and grading. This would seem to be confirmed by the fact that seasonal variations effect filter runs as well as the turbidity and organic content of the water.

I am sending you herewith a blue-print (Fig. 1.) showing a battery of seven small glass filters which were put in operation at Montebello Filters, Baltimore, Md., about three months ago for experimental purposes. This battery of filters was connected with the influent of one of our large filter units, which was run in conjunction with the test. The first unit was used as a control filter and the sand in it was taken from the large unit and was identical in every respect. The purpose of the control unit was to determine, if possible, whether the small experimental filter behaved exactly as the large one.

The experimental battery was erected in one of our filter galleries and the same surface of the control unit was maintained at the same level as the sand surface in the large unit. You will note that there is a single influent pipe, wash-water line, and monometer. When it became necessary to wash a filter, we simply cut off the other units. We found this was of no particular disadvantage. To pipe each filter with a complete equipment would mean a great many valves, fittings, and monometer tubes, and we can see no objection to the single pipe as shown on the drawing. However, I believe each experimenter should use piping to suit his own ideas. You will note from the connection of the piping shown on the drawing that the head maintained on all these filters is identical with that of the large unit, as they are fed from a common source.

We have been of the opinion that if a filter was equipped with a sand of a uniform size that each particle of floc would have an equal chance of being restrained by the sand layer in its passage toward the under-drains. We also believed that the sand should be fairly coarse. Our experience showed that bacterially and from the point of view of passing floc there seemed to be little difference as far as we could judge from our limited experience with the experimental filters. We were, however, greatly surprised to find that the filters which were most uniform and contained the coarsest sand gave decidedly the shortest runs. As yet we have been unable to account for this apparent fact.

We believe that it might well repay a series of careful experiments to see if we can learn more about filter sand. The operation of a filter like this can be worked under regular laboratory routine. The construction costs are not very great, the greatest cost being the glass tubes. At first, we tried some cheap glass tubes and found that they all broke; but we have broken no tubes made of Pyrex. Pyrex glass tubes cost about $7 each. We have used the small glass filters at Montebello for a number of years for the purpose of checking the application of chemicals to the water and have found them very satisfactory for that purpose. We believe these small units will give much more satisfactory results than might be supposed.

If you are willing to undertake such an experiment, we shall be glad to send you the sand already screened to put in the various filter units. By screening the sand here and sending it to the various operators we can insure

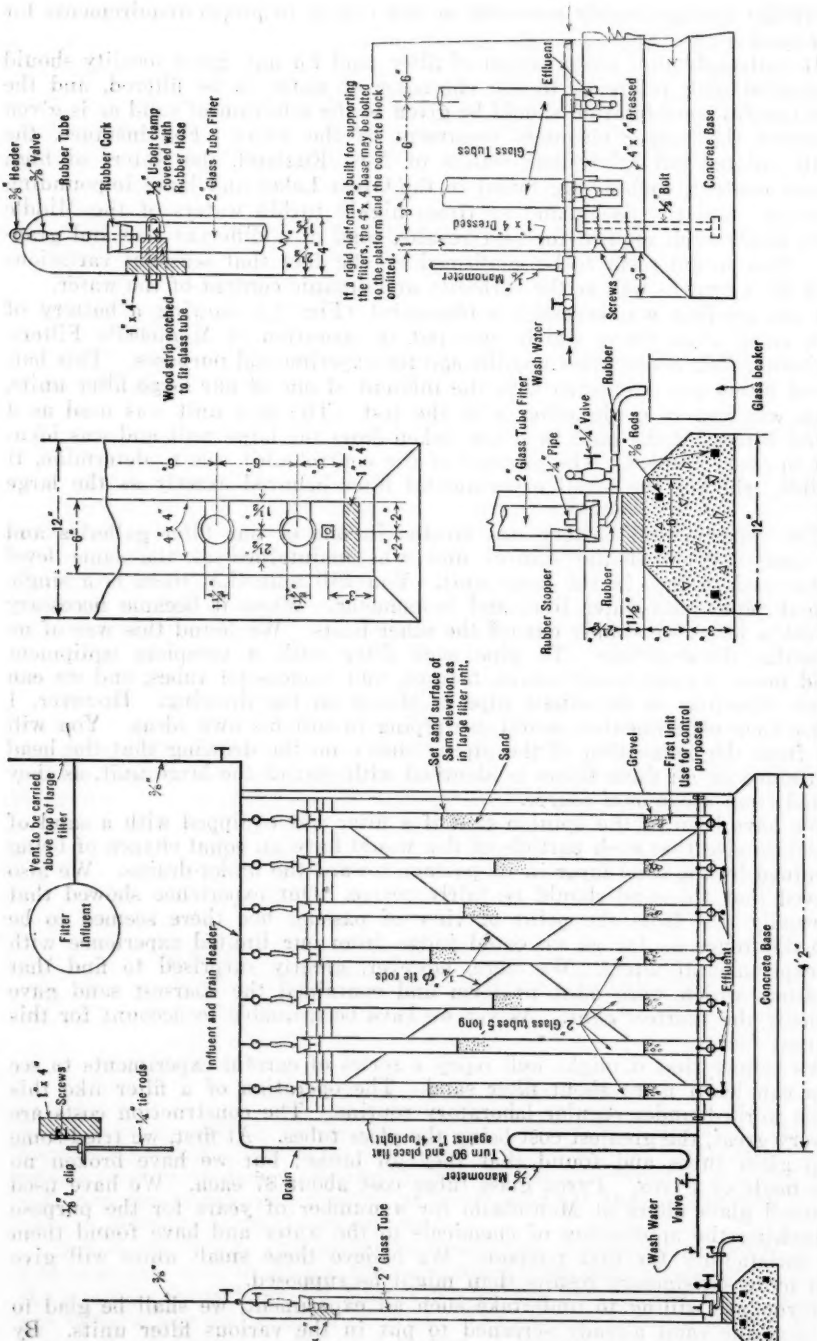

FIG. 1.—PLAN OF EXPERIMENTAL FILTER, BALTIMORE, MD.

identical sand sizes and there could be no question as to the uniformity of the experiments from that point of view.

We should appreciate hearing from you at an early date, as we wish to make report before the January meeting as to the number of those who are willing to undertake this experimental work. Any comments or suggestions you might have will be appreciated.

(2) *Copy of Letter to Parties Co-Operating in Experiments on Filter Sand.*—

"Lake Montebello, Hillen Road,
Baltimore, Maryland,
January 12th, 1928.

"GENTLEMEN.—We are sending you herewith 'Suggestions for Operating Experimental Filters'. This is sent as a tentative program for working. We invite your suggestions or criticism for its improvement or modification before sending out a final set of instructions to each of the operators co-operating with us in these tests. We are also enclosing the following blue prints:

"Chart showing depth and grading of sand to be used in the filters. (Fig. 2.)

"Diagram (tabulation) showing a general form proposed for making record of the filter runs.

"Curve for aid in determining the probable length of filter runs. (Fig. 3.)

"Two circulars descriptive of the turbidimeter.*

"We should appreciate your comments at as early a date as possible, so that we may have them in time to write the final instructions for conducting the experiments by the time the sand is ready for sending.

"Yours very truly,
"JAMES W. ARMSTRONG,
"Member of Committee."

AMERICAN SOCIETY OF CIVIL ENGINEERS
SANITARY ENGINEERING DIVISION
COMMITTEE ON FILTERING MATERIALS

SUGGESTIONS FOR OPERATING EXPERIMENTAL FILTERS

1.—Object of Experiment.—

The object of the experiment is to determine the optimum size of sand grains and the best depth and grading of the sand bed.

2.—Drawing of Filters.—

Drawings of the experimental filters have already been forwarded and no others will be sent except by special request.

3.—Erection of Small Units.—

Erection of small experimental units should preferably be in the filter gallery, and the piping should be so connected that the head on the small battery will be the same as that on the large unit. The top of the sand layer should be identical with the top of the sand layer in the large filter which is selected for use in the experiments. A good light should be provided for reading gauges and observing the action of the sand bed during the washing period.

* Copy not received with report.

FIG. 1.—PLAN OF EXPERIMENTAL FILTER, BALTIMORE, MD.

4.—Depth of Gravel.—

The gravel in the small filters is not easily displaced and need only be deep enough to support the fine gravel that holds the sand. Six inches should be sufficient.

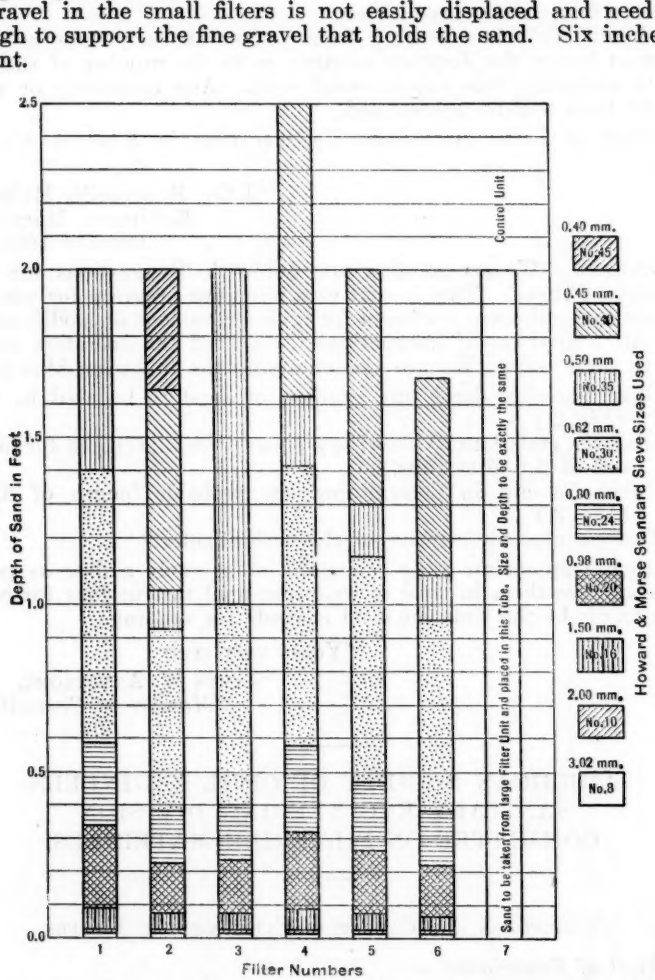

FIG. 2.—DEPTH AND GRADING OF SAND, SMALL EXPERIMENTAL FILTERS.

5.—Sand Sizes and Grading.—

Filter sand for the first six filters will be sent to each operator of the sizes indicated on the attached chart, entitled "Depth and Grading of Sand, Small Experimental Filters". (Fig. 2.) In the seventh, or control filter, the sand is to be taken from the large unit and placed in the control unit to the exact depth that it is in the large unit. By using a tube equipped with a thin metal gate for closing the bottom, which can be operated by turning a rod extending the full height of the tube, a sample can be collected when the filter is being washed, of the exact depth and grading as that in the original filter. You will note from the chart that we have not used the terms, "Uniformity Coefficient", or "Effective Size" for the reason that we do not believe these terms will have any meaning in the experiments which we hope to conduct. We have, however, plotted to scale the exact depth of each different size

of sand passing our screens as indicated in the explanation in the margin. The screen number is indicated by the figure in the little rectangle and above it is the size, in millimeters, of the sand retained upon the screen and passing the next larger size.

6.—Large Filter Unit.—

One large filter unit should be selected for operation in connection with the experiments. This filter should only be washed or put in service by special instructions of the person who is conducting the experiments. It is necessary in interpreting the results of these experiments to operate the filter under exactly the same conditions as the small units in order to make a comparison.

7.—Control Unit.—

Filter No. 7 has been selected as the control unit to establish the relationship between the large and small units. The sand should be taken from the large unit. We should naturally expect a difference in the performance of the control unit and the other units, due to the fact that one contains old seeded sand while the others contain fresh sand.

8.—Filter Numbers.—

In making reports and in correspondence, kindly refer to the filters by number as shown on Fig. 2, beginning from left to right and consider the large unit as No. 8.

9.—All Alike.—

If experiments of the kind we are undertaking are to be of any value, every experimental plant should be conducted as nearly as possible under the same conditions. Every variable should be eliminated and the equation should be reduced to a simple one of a single unknown quantity. The suggestions as outlined here are made in an effort to secure the necessary degree of uniformity, and may seem unnecessary to any one experienced in operating filters, but they are offered at this time as a basis for discussion in order to establish a final set of instructions before undertaking the experiments.

10.—Rate of Filtration.—

It is thought best to start the experiments at the ordinarily accepted rate for mechanical filters of 125 000 000 gal. per acre per day, and to maintain this rate as nearly uniform as possible throughout the entire time of the first set of experimental runs. The proper rate of filtration can be very readily secured by adjusting the clamps on the rubber effluent tubing. For a glass tube the internal dimension of which is $1\frac{3}{8}$ in., the effluent should be at a rate of 71 cu. cm. per min. This can be easily measured and checked in a graduated cylinder.

11.—Rate and Period of Washing.—

It is thought, at least for starting the experiments, that the rate of washing should be established at 2 ft. vertical rise per min. This will be somewhat more difficult to regulate than the rate of filtration, but it is believed it can be maintained fairly accurately by placing two valves on the wash-water line instead of one. One can be used as a stop-valve and the other as a regulating valve. In the tube $1\frac{3}{8}$ in. in diameter, a 2-ft. vertical rise per min. would give 532 cu. cm. per min. After the correct rate of washing has been secured, the control valve could have a handle taken off so that the rate could not be changed. It might be desirable to check the rate of wash at intervals.

12.—Time of Washing.—

For conducting the first set of experiments, the filters should be washed for 3 min. after the rate of 2 ft. vertical rise per min. has been reached.

13.—Procedure in Washing.—

Unless an operator is to be kept continuously on the experiments, it will be necessary to have some standard procedure in reference to washing filters.

In the battery which we have been operating at Montebello for a few months past, the following is approximately the method used

Each of the filters as it reaches the point where negative head begins is cut out of service and held without washing until the entire battery is out. About 10:00 A. M., after the run has been completed, the filters are all washed in regular rotation and immediately afterward put in service. They are allowed to run ½ hour before turbidity or bacterial samples are taken, as we have found in these small units that it takes about that time for the filter to clear before satisfactory samples can be obtained. After that, other readings are made at 2:00 P. M., and then each succeeding day at 10:00 A. M., and 4:00 P. M., until the filters run out. Obviously, with observations from 6 to 8 hours apart, it is not possible to tell exactly when any filter runs out. A number of curves have been prepared which will enable the operator by comparing the tend of any filter with the curves to interpret approximately the time. It is thought that if the length of filter runs is known within 2 or 3 hours, it will be satisfactory.

14.—Variations of Wash.—

It is thought that after conducting the experiments for a while at the rate of 2 ft. vertical rise per min., it might be well to vary the rate of wash.

15.—Length of Filter Runs.—

Length of filter runs (Fig. 3) should be considered complete when the mercury in the U-gauge stands at the same elevation in both legs. No negative head should be considered in these experiments.

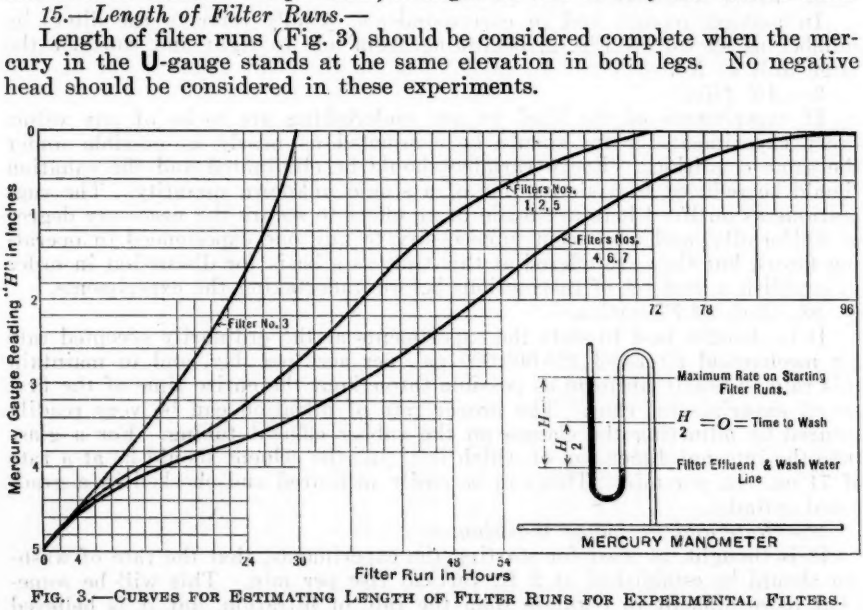
Mercury Gauge Reading "H" in Inches
Filter Run in Hours
Filter No. 3
Filters Nos. 1, 2, 5
Filters Nos. 4, 6, 7
Maximum Rate on Starting Filter Runs.
H/2 = O = Time to Wash
Filter Effluent & Wash Water Line
MERCURY MANOMETER

FIG. 3.—CURVES FOR ESTIMATING LENGTH OF FILTER RUNS FOR EXPERIMENTAL FILTERS.

16.—Lift of Sand.—

The height of sand as lifted above the bed during the maximum washing period should be observed and recorded, as it is believed this rise will vary considerably as the sand becomes coated with mud or organic matter. It may have an important bearing on the quantity of wash water required. A wax pencil mark should be made on the tube before washing, as a starting point for making the measurement.

17.—Turbidities.—

The turbidities cannot be properly indicated with the old-style turbidimeter. We are enclosing* a leaflet and a price list of the Baylis turbimeter as manufactured by the Levitt-Ferguson Company, of Baltimore. Turbidities

* Copies not received with report.

TABLE 5.—EXPERIMENTAL FILTERS, COMMITTEE OF FILTERING MATERIALS, AMERICAN SOCIETY OF CIVIL ENGINEERS.

CITY.....

NAMES OF PERSONS CONDUCTING EXPERIMENT { .....TITLE..... .....TITLE.....

DATE OF SHEET—BEGUN.....ENDED.....19....

REMARKS:

Date.	Turbidity, Raw water.	Turbidity, Settled water.	Color, raw water.	Alum, grains per gallon.	Total soap hardness, raw water.	pH., raw water.	Micro-organisms.	Time of wash.	Rate of wash, rise per minute.	Filter No. 1.* Length of filter run.	Filter No. 1.* Loss of head, in feet-tenths.	Filter No. 1.* Rise of sand.	Filter No. 1.* Turbidity.	Filter No. 1.* Color.	Filter No. 1.* Bacteria.	Large Filter No. 8. Length of filter run.	Large Filter No. 8. Loss of head, in feet-tenths.	Large Filter No. 8. Rise of sand.	Large Filter No. 8. Turbidity.	Large Filter No. 8. Color.	Large Filter No. 8. Bacteria.	Large Filter No. 8. Rate of flow.

* Repeat information for Filters Nos. 2 to 7, inclusive.

can easily be read within 0.1 of 1 part per million with this device. A similar instrument should be used. It can easily be home-made if it is not desired to purchase one.

18.—Bacterial Tests.—

It is thought for the purpose of comparative results, the only bacterial tests required will be plate counts on agar, incubated for 48 hours at 20° cent.

19.—Micro-Organisms.—

Micro-organisms should be reported at all plants where water is received from lakes or large impounding reservoirs or in places where they give trouble in plant operation. The number per cubic centimeter should be reported at least once on each filter run. Under the heading of "Remarks" the names of the predominating types should be mentioned.

20.—Recording Operating Data.—

We are enclosing a blank form (Table 5), as suggested for recording operating data.

21.—Reports.

Reports showing results of the experiments should be made at least once every three months and sent to Mr. James W. Armstrong, Lake Montebello, Hillen Road, Baltimore, Md. They will then be summarized and results sent to the different operators engaged in running these experiments.

Engineering Societies Library

The services of the Engineering Societies Library are available to all members who wish searches, copies, translations, etc., or advice on technical literature. A collection of modern books is also available for loan to members in North America, at moderate rentals. Correspondence should be addressed to the Director, Engineering Societies Library, 29 West 39th Street, New York, N. Y., who will gladly give information concerning the charges for the various kinds of work. A more comprehensive statement in regard to this matter will be found on pages 126 and 127 of the Year Book for 1927.

Book Notices*

(February 1 to February 29, 1928)

Baustoffverarbeitung und Baustellenprüfung des Betons. By A. Kleinlogel. Berlin u. Leipzig, Walter de Gruyter & Co., 1927. 106 pp., illus., diagrams, tab., 6 x 4 in., linen. 1,50 r.m.

Intended as a guide to superintendents of concrete construction and contractors, this book deals briefly with the testing of materials, methods of placing concrete, and the testing of finished work.

Construction Job Management. By Charles F. Dingman. N. Y., McGraw-Hill Book Co., 1928. 220 pp., illus., diagrams, tab., 7 x 4 in., fabrikoid. $2.50.

This volume deals successively with the preparatory work, equipment, directing the work, organizing, handling masonry work, fireproof construction, plastering, and carpentry, and relations with sub-contractors. Much practical advice is condensed into small space.

Hamilton Aerial Map of Manhattan. N. Y., Hamilton Aerial Map, 1927. Size of sheet, 32 x 34. Complete, with Binder, $55.00, plus service feature to Atlas owners; $1.00 per duplicate sheet. (For small area of the Island only, a pocket edition is published of one sheet for $3.00.)

This aerial map will cover Manhattan Island on a scale of 200 ft. to the inch. Fourteen sheets have been published, extending from the Battery to Fifty-ninth Street, and the remaining seventeen are being prepared.

Highway Engineering. By John H. Bateman. N. Y., John Wiley & Sons, 1928. 418 pp., illus., tables, 9 x 6 in., cloth. $4.00.

As an undergraduate textbook the author presents the fundamental theory with comprehensive descriptions of present practice. It discusses, successively, the economics, financing, location, design, construction, maintenance, and operation of highways.

New Towns for Old. By John Nolen. Bost., Marshall Jones Company, 1927. 177 pp., illus., 8 x 6 in., cloth. $3.00.

Mr. Nolen has here brought together some representative examples of civic improvement showing how old industrial towns have been improved, how new ones have been built to order, and how residential suburbs of a high class have been made attractive.

Permanent-Way Material Plate-Laying and Points and Crossings. By W. H. Cole. Ninth Edition, rev. by Gordon Hearn. Lond., E. & F. N. Spon, 1928. 245 pp., diagrams, tab., 7 x 5 in., cloth. 12/6.

This standard English book treats of track standards, rails, and accessories, construction, maintenance, switches and crossings, and signaling and interlocking.

* The statements made in these notices are taken from the books themselves, and this Society is not responsible for them. Unless otherwise specified, the books in this list have been donated by publishers.

Plumbing. By Harold E. Babbitt. N. Y., McGraw-Hill Book Co., 1928. 455 pp., illus., diagrams, tab., 9 x 6 in., cloth. $5.00.

Containing the latest standard practices in the design and installation of plumbing, this book is comprehensive and practical and distinguished by the explanation of scientific principles.

Principles of Highway Engineering. By Carroll Carson Wiley. N. Y., McGraw-Hill Book Co., 1928. 510 pp., illus., tab., 9 x 6 in., cloth. $4.00.

In this book, the material has been selected to illustrate the various principles and practices so that the college student of highway engineering can absorb them in the available time.

Theory of Structures. By Charles M. Spofford. Third Edition. N. Y., McGraw-Hill Book Co., 1928. 587 pp., diagrams, tab. 9 x 6 in., cloth. $6.00.

This well-known text deals almost entirely with statically determined structures. In this edition, chapters on space framework and on frameworks of high buildings have been added.

Additions to the Reading Room

The Civil Engineer's Pocket-Book. By John C. Trautwine. Rev. by the late John C. Trautwine, Jr., M. Am. Soc. C. E., and John C. Trautwine, 3d, M. Am. Soc. C. E. Twentieth Edition. Wallingford, Pa., Trautwine Co., 1919; Lond., Chapman & Hall, Ltd.; Montreal, Renouf Pub. Co. 1 600 pp., diagrams, tab., 7 x 4 in., cloth. (Gift of Mr. John C. Trautwine, 3d.)

One of the leading objects of this book has been to elucidate, in plain English, a few important elementary principles for the younger members of the Engineering Profession. The numerous and extensive changes in this, the Twentieth Edition, include approximately 400 pages that have been added to the section on Railroads.

Current Civil Engineering Literature

Key to Abbreviated References to Publications Indexed*

Abbreviated References.	Publication.	Place.
Am. C. Inst.	*American Concrete Institute, Proceedings* (Y.)	Detroit
A. I. E. E.	*American Institute of Electrical Engineers Journal* (M.)	New York
A. R. E. A.	*American Railway Engineering Association, Proceedings* (Y.)	Chicago
A. S. T. M.	*American Society for Testing Materials, Proceedings* (Y.)	Philadelphia
Am. Soc. C. E.	*American Society of Civil Engineers, Proceedings* (M.)	New York
Am. Soc. Mun. Impvts.	*American Society for Municipal Improvements, Proceedings* (Y.)	New York
Am. W. W. Assoc.	*American Water Works Association, Journal* (M.)	Baltimore
Am. Wood Prs. Assoc.	*American Wood Preservers Association, Proceedings* (Y.)	Chicago
Ann. P. et C.	*Annales des Ponts et Chaussées* (Bi-M.)	Paris
Ann. T. P. Belg.	*Annales des Travaux Publics de Belgique* (Bi-M.)	Brussels
Assoc. Ing. Gand.	*Annales de l'Association des Ingénieurs sortis des Ecoles Spéciales de Gand* (Q.)	Ghent
Bost. Soc. C. E.	*Boston Society of Civil Engineers, Journal* (M.)	Boston
Can. Engr.	*Canadian Engineer* (W.)	Toronto
City Plan.	*American City Planning Institute* (Q.)	Boston
Comwlth Engr.	*Commonwealth Engineer* (M.)	Melbourne
Cornell C. E.	*Cornell Civil Engineer* (M.)	Ithaca
Dock & Harbour	*Dock and Harbour Authority* (M.)	London
Eng.	*Engineering* (W.)	London
Eng. & Contr.	*Engineering and Contracting* (M.)	Chicago
Eng. Inst. Can.	*Engineering Institute of Canada, Journal* (M.)	Montreal
Eng. N. R.	*Engineering News-Record* (W.)	New York
Engr. Soc. W. Pa.	*Engineers' Society of Western Pennsylvania, Journal* (M.)	Pittsburgh
Engr.	*Engineer* (W.)	London
Engrs. & Eng.	*Engineers and Engineering, Engineers' Club of Philadelphia* (M.)	Philadelphia
Gas und Wasser.	*Gas und Wasserfach*	Munich
Gen. Civ.	*Le Génie Civil* (W.)	Paris
Gesund. Ing.	*Gesundheits Ingenieur* (W.)	Munich
Inst. C. E.	*Institution of Civil Engineers Minutes of Proceedings* (Q.)	London
Inst. Mun. & Co. Engrs.	*Institution of Municipal and County Engineers, Journal* (W.)	London
Int. Ry. Cong. Assoc.	*International Railway Congress Association, Bulletin* (M.)	Brussels
Land. Arch.	*Landscape Architecture* (Q.)	Boston
Mech. Eng.	*Mechanical Engineering* (M.) *Journal of the American Society of Mechanical Engineers*	New York
Mil. Engr.	*Military Engineer* (Bi-M.)	Washington
Min. & Metal.	*Mining and Metallurgy* (M.) *American Institute of Mining Engineers*	New York
Mun. N.	*Municipal News* (M.)	Chicago
N. E. W. W. Assoc.	*New England Water Works Association, Journal* (Q.)	Boston
N. Y. R. R. Club	*New York Railroad Club, Proceedings* (M.)	Brooklyn
Oest. Ing. Arch. Ver.	*Oesterreichischer Ingenieur und Architekten Verein, Zeitschrift* (F.)	Vienna
Power	*Power* (W.)	New York
Public W.	*Public Works* (M.)	New York
Rev. Gen.	*Revue Générale des Chemins de Fer* (M.)	Paris
Ry. Age	*Railway Age* (W.)	New York
Ry. Eng. & Main.	*Railway Engineering and Maintenance* (M.)	Chicago
R. & S.	*Roads and Streets* (M.)	Chicago
Schw. Bauz.	*Schweizerische Bauzeitung* (W.)	Zurich
Sci. Am.	*Scientific American* (M.)	New York
Soc. Ing. Civ. Fr.	*Société des Ingénieurs Civils de France, Mémoires et Comptes Rendus* (Q.)	Paris
Tech. Gemein.	*Technisches Gemeindeblatt* (F.)	Berlin
Ver. deu. Ing.	*Verein deutscher Ingenieure, Zeitschrift* (W.)	Berlin
W. W.	*Water Works* (M.)	Chicago
West. Constr. N.	*Western Construction News* (F.)	San Francisco
West. Ry. Club	*Western Railway Club, Proceedings* (M.)	Chicago
West. Soc. Engrs.	*Western Society of Engineers, Journal* (M.)	Chicago
Zeit. Bau.	*Zeitschrift für Bauwesen* (Q.)	Berlin
Z. d. Bauver.	*Zentralblatt der Bauverwaltung* (W.)	Berlin

* Y = Yearly; Q = Quarterly; M = Monthly; F = Fortnightly; W = Weekly.

A. Applied Sciences

a. Processes of Calculation

2. Graphical and Nomographical Processes

Vorschläge zur Vereinheitlichung der Ausführung nomographischer Rechentafeln.* (Proposals for Standardizing the Construction of Nomographic Calculation Tables.) Günther Oberdorfer. Oest. Ing. Arch. Ver. Jan. 20, '28.

B. Applied Mechanics

a. Mechanics of Solids (Strength of Materials)

Les Propriétés de la Matière sous les Hautes Pressions. (The Properties of Matter under High Pressures.) A. Boutaric. Gen. Civ. Dec. 31, '27.

4. Riveted Systems

Tensile Working Stress for Rivets Investigated.* C. R. Young. (From paper read before Am. Inst. Steel Constr.) Eng. N. R. Feb. 2, '28.

5. Homogeneous Inelastic Solids

The Compressibility of Sand-Mica Mixtures.* Glennon Gilboy. Am. Soc. C. E. Feb., '28.

6. Heterogeneous Solids (Reinforced Materials)

Calcul des hourdis des tabliers d'ouvrages d'art en béton armé.* (Calculation of Floor Slabs in Reinforced Concrete Constructions.) F. Chaudy. Gen. Civ. Serial beginning Jan. 28, '28.

b. Hydraulics

2. Physical Hydraulics

Building a Penstock to Develop a Static Head of 2,561 Ft.* Oswald Speir, Jr. Eng. N. R. Feb. 2, '28.

Nebenströmungen in gekrümmten Kanälen.* (Secondary Flow in Curved Channels.) A. Hinderks. Ver. deu. Ing. Dec. 17, '27.

3. Industrial Hydraulics

Approximate Formulas for Arch Dam Design.* B. F. Jakobsen. Eng. & Contr. Jan., '28.

High-Head Hydro-Electric Project on Bucks Creek.* Eng. N. R. Jan. 26, '28.

Silting of the Lake at Austin, Texas.* T. U. Taylor. Am. Soc. C. E. Feb., '28.

Water-Power Appraisals. Discussion: Joel D. Justin, Dana M. Wood, and Franklin H. Davis. Am. Soc. C. E. Feb., '28.

New Theory for the Centrifugal Pump. Discussion: Elmer G. Hooper. Am. Soc. C. E. Feb., '28.

Precise Weir Measurements.* Discussion: A. Streiff. Am. Soc. C. E. Feb., '28.

America's Greatest Water-Wheel.* Charles W. Geiger. Sci. Am. Feb., '28.

The Conowingo Hydro-Electric Development on the Susquehanna River. Discussion: H. A. Hageman. Am. Soc. C. E. Feb., '28.

Falls of the Ohio to Produce 100 000 Kw.* Power Feb. 7, '28.

Power Development at Bridge River, B. C. Can. Engr. Feb. 7, '28.

Three Dams on Bucks Creek Project, Feather River Power Company, California.* Culbert W. Faries. West. Constr. N. Feb. 10, '28.

The Maentwrog Power-house of the North Wales Power Company. Engr. Feb. 10, '28.

Hydro Development at Paugan Falls.* R. C. Rowe. Can. Engr. Feb. 21, '28.

Das Grosskraftwerk Klingenberg.* (The Large Klingenberg Power Plant.) Ver. deu. Ing. Dec. 31, '27.

Alte Pumpenspeicheranlagen im Harz.* (Old Pump Reservoirs in the Harz.) Ziegler. Ver. deu. Ing. Jan. 21, '28.

Das Grosskraftwerk Ryburg-Schwörstadt am Rhein.* (The Ryburg-Schwörstadt Large Power Plant on the Rhine.) Dr. Robert Haas. Ver. deu. Ing. Jan. 21, '28.

4. Dams

The Evergreen Dam, Bear Creek, Colorado.* N. C. Hartford. West. Constr. N. Jan. 10, '28.

Construction of Multiple-Arch Dam in Arizona.* Eng. N. R. Feb. 2, '28.

x. Miscellaneous

Application of Laboratory Research to the Study of Hydraulic Problems.* George H. de Thierry. Bost. Soc. C. E. Jan., '28.

C. Materials of Construction and General Processes

a. Lime, Cement, Mortar, Concrete, Brick, Bitumen, Timber, etc.

The Dunstable Portland Cement Works.* Engr. Serial beginning Jan. 27, '28.

Modern Portland Cement Plant.* Hal Gutteridge. Dock & Harbour Feb., '28.

Extensometer for the Determination of Young's Modulus for Concrete. V. C. Davies. Eng. Feb. 3, '28.

Action of Pure water on Cement Mortar Briquets.* Eng. N. R. Feb. 9, '28.

Compressive Stress on Wood Surfaces Inclined to the Grain.* William R. Osgood. Eng. N. R. Feb. 9, '28.

Consistency of Silicate of Soda for Curing Concrete.* Robert S. Beightler. Eng. N. R. Feb. 23, '28.

Recherches sur la Perméabilité des Bétons, "calcaires-silicate de soude."* (Researches on the Permeability of Concrete: Calcareous Silicate of Soda.) P. Deslandres. Gen. Civ. Jan. 21, '28.

b. Metals

L'essai de corrosion des aciers.* (Testing the Corrosion of Steels.) Gen. Civ. Jan. 28, '28.

Die internationale Giessereifachausstellung in Paris.* (The International Foundry Exhibition in Paris.) U. Lohse. Ver. deu. Ing. Jan. 7, '28.

c. Preservation and Use of Materials, Painting, Waterproofing

Framing Structural Timbers Before Treatment. Earl Stimson. (From paper read before Am. Wood Preservers' Assoc.) Ry. Eng. & Main. Feb., '28.
Chemical Reactions of Wood Fungi.* Leo P. Curtin. (From paper read before Am. Wood Preservers' Assoc.) Can. Engr. Feb. 21, '28.

e. Earthwork. Cubage. Excavating Machinery

Building a Pumping Station Under Difficulties.* Eng. & Contr. Jan., '28.

f. Rock Excavation, Mining, Rock Removal

Die neuen Transportanlagen im Steinbruch Alpnach-Guber.* (The New Transportation System in the Alpnach-Guber Quarry.) F. Steiner. Schw. Bauz. Jan. 7, '28.

g. Execution of Works, Specifications

How to Prevent Termite Damage to Buildings.* Thomas E. Snyder. Eng. N. R. Feb. 16, '28.

1. Of Masonry

Some Practices in Erecting Damp-Proof Tile-and-Brick Walls.* P. H. Bevier. Eng. N. R. Feb. 16, '28.

2. Of Concrete

Die Festigkeiten von Beton mit verschiedenem Wasserzusatz. (The Strengths of Concrete with different Proportions of Water.) Richard Grün & Günther Künze. Z. d. Bauver. Jan. 18, '28.

4. Of Metal

Welding Trusses for Industrial Buildings.* Andrew Vogel. (Paper read before Aff. Tech. Soc. Boston.) Eng. & Contr. Jan., '28.
Steelwork for the Royal Bank Building in Montreal.* R. M. Robertson. Eng. Inst. Can. Feb., '28.

5. Of Reinforced Concrete

Stress in Reinforced Concrete Chimneys.* Peter Gillespie and W. K. Irwin. Can. Engr. Jan. 24, '28.
Reinforced-Concrete Wall Moved 1 000 Ft.* Eng. N. R. Feb. 9, '28.
Die neuen österreichischen Eisenbetonbestimmungen. (The New Austrian Ferro-Concrete Regulations.) Z. d. Bauver. Jan. 4, '28.

h. Foundations, Bridge Piers and Abutments

The Foundations for the New Building of the Royal Bank of Canada, Montreal.* C. S. Proctor. Eng. Inst. Can. Feb., '28.
The Science of Foundations—Its Present and Future.* Discussion: George Paaswell, C. C. Williams, and Herbert Chatley. Am. Soc. C. E. Feb., '28.
Waterfront Foundation Complicated by Buried Log Cribs.* Ralph H. Chambers. Eng. N. R. Feb. 16, '28.

i. Coffer-dams

The Construction of a Cofferdam.* George A. Follett. Mil. Engr. Jan.–Feb., '28.

k. Tunnels and Tunneling-Shields

Construction of the Moffat Tunnel.* Charles G. Gabelman. Mil. Engr. Jan.–Feb., '28.
Ventilation in Driving Subway Tunnels.* W. F. Boericke. Min. & Metal. Feb., '28.
Vehicular Tunnels Through Missionary Ridge.* G. R. Kavanagh. Pub. W. Feb., '28.
Concrete Gun Lining Work in Duboce Tunnel.* Eng. N. R. Feb. 2, '28.
Traveling Concrete Plants Line Cascade Tunnel.* Eng. N. R. Feb. 9, '28.

D. Highways

c. Construction

Evaluation of Sands for Sheet Asphalt Pavements.* Prevost Hubbard and F. C. Field. (From paper read before Annual Asphalt Paving Conference.) R. & S. Jan., '28.
Stone Bases for Asphalt Wearing Courses.* E. N. Seymour. (Annual Asphalt Paving Conference.) R. & S. Jan., '28.
One Course Concrete Curb Construction.* (From *Concrete Highways.*) R. & S. Jan., '28.
Survey of Surface Treatment Field.* C. N. Conner. (Paper read before Annual Asphalt Paving Conference.) R. & S. Jan., '28.
Penetration Macadam in Illinois Towns.* R. & S. Jan., '28.
Heavy Grading for Future State Highway.* R. & S. Jan., '28.
New Link in Famous Old Mountain Highway Now Paved.* Sam. S. Porter. R. & S. Jan., '28.
Asphalt Mixtures and Gradings.* E. Barton Hack. Comwlth. Engr. Jan. 2, '28.
Emulsified Cold Bitumen and Its Uses. David Torrance. Inst. Mun. & Co. Engrs. Jan. 10, '28.
Low-Cost Improved Roads. (From Report of Highway Research Board.) Pub. W. Feb., '28.
Constructing New Mexico Gravel Road.* F. D. Hawley. Pub. W. Feb., '28.
Drained Paving Used to Stabilize Road on Sliding Side Hill.* Eng. N. R. Feb. 2, '28.
Concrete Base for Asphalt Pavements. Roy M. Green. (Paper read before Asphalt Pav. Conference.) Can. Engr. Feb. 7, '28.
Measurement of Concrete Materials.* R. T. Giles. (Paper read before Am. Road Bldrs. Assoc.) Can. Engr. Feb. 7, '28.
Asphaltic Concrete Paving Practice in Denver, Colo.* Eng. N. R. Feb. 9, '28.
Oiled Macadam Road Construction of Soft Stone.* B. E. Gray. (Extract from paper read before Highway Research Board, Wash., D. C.) Eng. N. R. Feb. 16, '28.
La Fabrication des Briques de Pavage et leur Emploi pour les Revêtements de Routes.* (The Manufacture of Paving Bricks and Their Use for Road Coverings.) Gustave Colliez. Gen. Civ. Jan. 14, '28.

La Strada di Gandria.* (The Gandria Road.) Carlo Jegher. Schw. Bauz. Jan. 14, '28.
Neuartige Fugeneinlageisen mit ineinandergreifenden Verzahnungen.* (New Type of Inserted Iron Joint With Intermeshing Teeth.) Oest. Ing. Arch. Ver. Jan. 6, '28.

d. Maintenance

The Drainage of "Flat" Roads.* F. Batterbury. Inst. Mun. & Co. Engrs. Jan. 24, '28.

f. Tree Planting

Roadside Tree Planting. (From *California Highways.*) R. & S. Jan., '28.

h. Vehicles, Automobiles, Traffic

Chicago Advocates Progressive Control System.* R. & S. Jan., '28.
Brick-Paved Roads. Eng. Jan. 27, '28.
Relation of Road Type to Tire Wear. Discussion: O. L. Waller and H. E. Phelps. Am. Soc. C. E. Feb., '28.
Signals for Highway Intersections.* Lewis E. Moore. Eng. N. R. Feb. 9, '28.

E. Bridges, Viaducts and Arches

a. Timber Bridges and Viaducts

Stress Analysis of 90-Year-Old Wooden Bridge.* Nelson J. Bell and J. K. Grannis. Eng. N. R. Feb. 9, '28.

b. Iron and Steel Bridges and Viaducts

The New Brisbane River Bridge.* Comwlth. Engr. Jan. 2, '28.
High-Strength Steels for Modern Bridges. L. S. Moisseiff. (From paper read before N. Y. Sec., Am. Soc. Steel Treat.) Eng. N. R. Jan. 26, '28.
Problems in Fabricating Silicon Steel for Delaware Bridge. H. T. Morris. (From paper read before N. Y. Section, Am. Soc. Steel Treat.) Eng. N. R. Feb. 9, '28.
Bridge 502 Ft. Above Stream Bed Built in Idaho.* R. M. Murray. Feb. 16, '28.
Bridges Over the Welland Ship Canal.* Marshall Brodie Atkinson. Eng. Inst. Can. Feb., '28.
Die Eisenbahn-Notbrücke zwischen Buchs und Schaan.* (The Emergency Railway Bridge between Buchs and Schaan.) A. Buhler, Schw. Bauz. Dec. 17, '27.
Neubau der Strassenbrücke über die Iller bei Kellmünz.* (Rebuilding the Highway Bridge Over the Iller at Kellmünz.) Hohenleitner. Z. d. Bauver. Jan. 4, '28.

c. Stone Bridges and Viaducts

Crown Stresses in a Skew Arch.* J. Charles Rathbun. Am. Soc. C. E. Feb., '28.

d. Concrete and Reinforced Concrete Bridges and Viaducts

Bridging Some Highways Through Jungle of Lower Burma.* Alan S. Carr. Inst. Mun. & Co. Eng. Jan. 24, '28.
Des Lignes d'Influence Application au Calcul d'un Pont en Arc Continu à la Clef et Encastré aux Naissannes.* (Influence Lines. Application to the Calculation of a Continuous Arch Bridge and Fixed at the Springings.) Paul J. Rullens. Ann T. P. Belg. Dec., '27.

f. Suspension Bridges. Transfer Bridges

The Eye-Bar Cable Suspension Bridge at Florianopolis, Brazil. Discussion: Hardy Cross. Am. Soc. C. E. Feb., '28.

F. Inland Waters

a. Natural Waterways (General Articles)

The Improvement of the River St. Lawrence.* E. W. Lane. Eng. Serial beginning Jan. 20, '28.
Advances in Waterways Engineering During a Half Century. Discussion: C. L. Hall and DeWitt D. Barlow. Feb., '28.
L'Ourthe Supérieure. Note Complémentaire.* (The Upper Ourthe. Additional Note.) J. Duvigneaud. Ann. T. P. Belg. Dec., '27.

b. Canals (General Articles)

Chippawa Creek Syphon Culvert of the Welland Ship Canal.* A. J. Grant. Eng. Inst. Can. Feb., '28.
The Lake Washington Ship Canal, Washington. Discussion: W. J. Barden and A. W. Sargent. Am. Soc. C. E. Feb., '28.
Les Tendances Nouvelles dans la Construction des Ouvrages de Navigation Intérieure en Europe Centrale.* (Modern Trends in Constructions for Inland Navigation in Central Europe.) A. Genthial. Gen. Civ. Serial beginning Dec. 17, '27.

c. Regulation of Waterways—Volume of Discharge, Freshets, Floods, Soundings

Side Spillways for Regulating Diversion Canals. Discussion: Edward S. Lindley. Am. Soc. C. E. Feb., '28.
Curbing the Mississippi.* J. Bernard Walker. Sci. Am. Feb., '28.
Maximum Flood Discharge in San Joaquin Valley, California.* Discussion: Robert Follansbee and Harold K. Fox. Am. Soc. C. E. Feb., '28.
Maintenance of Flood-Control Works of Miami District.* C. S. Bennett. Eng. N. R. Feb. 2, '28.

Forecasting Mississippi Flood Stages.* Isaac M. Cline. Eng. N. R. Feb. 16, '28.
Die Regulierung der Spree mit besonderer Berücksichtigung der oberen, schiffbaren Spree von Leibsch bis Fluthkrug.* (The Regulation of the Spree with Special Consideration of the Upper Navigable Spree from Leibsch to Fluthkrug.) R. P. Muller. Zeit. Bau., Heft VIII, '27.

d. Diverting Dams, Locks, Lifts, Elevators, Inclined Planes

The Lock Gates of the Welland Ship Canal.* Frank E. Sterns. Eng. Inst. Can. Feb., '28.
Emergency Dam on Inner Navigation Canal at New Orleans, Louisiana. Discussion: F. R. Harris and R. H. Whitehead. Am. Soc. C. E. Feb., '28.
Three Dams on Bucks Creek Project, Feather River Power Company, California.* Culbert W. Faries. West. Constr. N. Feb. 10, '28.
Renouvellement des Heurtoirs des barrages-éclusés de la Meuse liégeoise.* (Renewal of the Buffers of the Dam Locks on the Liege Meuse.) C. Houart. Ann. T. P. Belg. Dec., '27.

g. Consolidation of Banks, Leakage, etc.

The Great Yangtze Bar. Discussion: R. L. Vaughn. Am. Soc. C. E. Feb., 28.

k. Utilization of Inland Waterways, Freight, Capacity

Preservation of Horseshoe Falls, Niagara.* Can. Engr. Jan. 31, '28.

G. Maritime Works

a. Behavior of Movements of the Ocean

Inlets on Sandy Coasts.* Earl I. Brown. Am. Soc. C. E. Feb., '28.

c. Vessels and Maritime Navigation, Lighthouses, Buoys, Various Signals

The Canadian Pacific Cargo Steamer Beaverburn.* Engr. Jan. 13, '28.
Fresnel et les Progrès de la Signalisation Maritime.* (Fresnel and Progress in Maritime Signalling.) A. de Rouvell. Gen. Civ. Dec. 31, '27.
Les Compas Gyroscopiques employés à bord des navires et des aéronefs.* (The Gyro-Compass Used on Vessels and Aircraft.) Guy Malgorn. Gen. Civ. Jan. 14, '28.
Le Paquebot à moteurs Diesel "Augustus" de la Compagnie Navigazione Generale Italiana.* (The Diesel Vessel "Augustus" of the Compagnie Navigazione Generale Italiana.) Olivier Quéant. Gen. Civ. Jan. 21, '28.
Zweischwimmerhebewerk mit beweglicher Troglagerung.* (Double-Float Ship Elevator with Movable Trough Bearing.) Vollmer & Mussaeus. Z. d. Bauver. Jan. 25, '28.

g. Dredges and Dredging. Force Pumps. Refloating and Removing Wrecks. Ice-Breakers

Submarine Safety and Salvage Devices.* Mech. Eng. Feb., '28.
The Salvage of T. S. S. "Nagara".* Eng. Feb. 10, '28.

h. Wharves, Mooring Buoys, Harbor Equipment

Erie Builds Large Modern Pier in New York Harbor.* Ry. Age Jan. 21, '28.

i. Harbors

The Self-Managing Port of Bordeaux.* Dock & Harbour Feb., '28.
The Ports of Rumania.* Roy. S. MacElwee and Henry F. Church. Dock & Harbour Serial beginning Feb., '28.
The Development of Bluff Harbour.* Dock & Harbour Feb., '28.

H. Railroads. Street and Interurban Railways. Automobiles. Aeronautics

a. Railroads

1. General Articles

Fighting the Great Flood.* C. R. Knowles. (From paper read before Am. Ry. Bridge & Bldg. Assoc.) Ry. Eng. & Main. Jan., '28.
New England Railroads Restore Flood-Wrecked Lines to Service.* Ry. Eng. & Main. Feb., '28.
Sixty-Three-Mile Railway Completed in Ten Months.* Eng. N. R. Feb. 23, '28.
Improved Methods Used in Surveys for Extending Piedmont & Northern Railway.* Eng. N. R. Feb. 23, '28.
Motor Truck and Light Cars Used to Dismantle 165-Mile Railway.* T. E. Rust. Eng. N. R. Feb. 23, '28.

3. Roadbed (Grading Construction Work)

Will a Concrete Roadbed Stand Up?* Ry. Eng. & Main. Jan., '28.
Cleaning Ballast at the Rate of a Mile a Day.* Ry. Eng. & Main. Jan., '28.
What One Year's Service on Concrete Roadbed Has Shown.* Paul Chipman. (From paper read before Main. of Way Club.) Ry. Age Jan. 14, '28.
An Unusual Development in Labor Saving Equipment.* Ry. Age Jan. 28, '28.
Der Hindenburgdamm (Bahnlinie Niebüll-Westerland).* (The Hindenburg Dam (Niebüll-Westerland Railway.)) Von Kümmel. Ver deu. Ing. Jan. 14, '28.

4. Track

What Makes Good Street Railway Track.* Frank B. Walker. (Paper read before Am. Elec. Ry. Eng. Assoc.) Eng. & Contr. Jan., '28.
String Lining of Curves Made Easy. Charles H. Bartlett. Ry. Eng. & Main. Jan., '28.
Distribution of Wheel Loads on Small-Span Open-Deck Openings in Railway Track.* T. A. Farrent. (Paper read before A. I. E. Aust.) Comwlth. Engr. Jan. 2, '28.

Care of Ties Pays Large Returns on the Lackawanna.* George J. Ray. (From paper read before Am. Wood Preservers' Assoc.) Ry. Eng. & Main. Feb., '28.
How to Measure a Curve for String Lining.* Charles H. Bartlett. Ry. Eng. & Main. Feb., '28.
Building Snow Fences of Trees.* Ry. Eng. & Main. Feb., '28.
Broadgaging the N-C-O Railway.* Eng. N. R. Feb. 23, '28.
Economics of Treated Ties on the Lackawanna Railroad.* Eng. N. R. Feb. 23, '28.
La Fabrication de Rails Sains par le procede de laminage Courthéoux.* (The Manufacture of Sound Rails by the Courthéoux Rolling Process.) Louis Pichard. Gen. Civ. Dec. 31, '27.
Les fissures transversales superficielles des rails.* (The Superficial Transverse Cracks of Rails.) Ch. Dantin. Gen. Civ. Jan. 21, '28.

5. Signals and Safety Apparatus

Pennsylvania Installs Code System of Train Stop with Signaling.* Ry. Age Jan. 14, '28.
Rock Island Increases Track Capacity by Either-Direction Signaling.* Leroy Wyant. Ry. Age Feb. 11, '28.

6. Rolling Stock (Locomotives, Cars) Fuel

The Schmidt-Henschel High-Pressure Locomotive.* Engr. Jan. 20, '28.
Measure of Locomotive Utilization.* George W. Armstrong. Ry. Age Jan. 28, '28.
Preventing Excessive Smoke.* J. F. Bjorkholm. (Abstract of paper read before Comm. on Smoke Abatement, Kansas City.) Ry. Age Feb. 11, '28.
Le Choix d'un Type de Wagons à Marchandises pour les Chemins de Fer Coloniaux.* (The Selection of a Type of Freight Car for the Colonial Railways.) M. Nicolas. Gen. Civ. Jan. 28, '28.
Voitures semi-métalliques de 2e Classe pour Grandes Lignes du Réseau D'Alsace et de Lorraine.* (Second-Class Semi-Metallic Cars for Main Lines of the Alsace and Lorraine System.) Renevey. Rev. Gen. Jan., '28.
Die Neuen 1 C C 1 Güterzug-Lokomotiven der Schweizer. Bundesbahnen.* (The New 1 C C 1 Freight Locomotives for the Swiss Federal Railways.) Schw. Bauz. Nov. 12, '27.

7. Use of Electricity

Illinois Central Suburban Service.* W. M. Vandersluis. A. I. E. E. Feb., '28.
Motoriokomotiven mit elektrischer Kraftübertragung, System "Gebus".* (Motor Locomotives with Electric Power Transmission, "Gebus" System.) Otto Judtmann. Oest. Ing. Arch. Ver. Jan. 6, '28.

8. Stations, Terminals, Engine Houses, Shops

Daily Cost Figures a Valuable Aid.* Ry. Age Jan. 21, '28.
Comprehensive Reports Speed Yard Operations at Selkirk.* Ry. Age Jan. 28, '28.
New Income and the Service of Supply.* Marion J. Wise. Ry. Age Feb. 4, '28.
Freight Transfer Operation Aided by Tonnage System.* Ry. Age Feb. 4, '28.
Car Retarders at Mechanicville.* Ry. Age Feb. 4, '28.
How a Complex Yard Problem Has Been Solved.* Ry. Age Feb. 11, '28.
Rebuilding of North Station in Boston Under Way. Eng. N. R. Feb. 23, '28.
Large Terminal Yard and Transfer Station.* Eng. N. R. Feb. 23, '28.
Note sur les Garages Installés à Pantin par la Compagnie des Chemins de Fer de l'Est pour l'Entretien de ses Voitures (Garages de l'Ourcq).* (Note on the Garages Built at Pantin by the Compagnie des Chemins de Fer de l'Est for the Maintenance of Its Cars (Ourcq garages)). M. J. Monet. Rev. Gen. Jan., '28.
Nouvelle Organisation de Travail dans les Ateliers de Dépôts de la Compagnie d'Orléans.* (New Organization of Work in the Station Shops of the Compagnie d'Orléans.) M. J. Pezeu. Rev. Gen. Jan., '28.

x. Miscellaneous

The Application of Model Experiments to the Air Resistance of Trains. Engr. Feb. 10, '28.

b. Special Railroads

2. Aerial Railroads

Berechnung von Seilfähren.* (Calculation of Cableways.) Franz Skrobanek. Oest. Ing. Arch. Ver. Jan. 6, '28.

c. Ferry Boats

The Danish Motor Train-Ferry "Korsor." Eng. Jan. 13, '28.
Three-Track Car-Ferry Landing; Wabash Railway.* S. M. Smith. Eng. N. R. Feb. 9, '28.

d. Street Railways, Elevated Railways, Subways

1. General Articles

University Avenue Extension Scheme.* A. G. Dalzell. Can. Engr. Jan. 24, '28.
The Post Office Tube Railway, London.* Eng. Serial beginning Jan. 27, '28.

e. Automobiles

x. Miscellaneous

Les Methodes Appliquées à la S. T. C. R. P. pour l'Entretien des Autobus et des Tramways.* (The Methods Used on the S. T. C. R. P. for the Maintenance of Autobusses and Tramways.) G. Delanghe. Gen. Civ. Jan. 14, '28.

f. Aeronautics

1. General Articles

N. A. T. Country's Largest Air Transport Line.* Ry. Age Jan. 14, '28.

3. Aeroplanes

Tuning Up Transatlantic Motors.* T. H. Kinkade. Sci. Am. Feb., '28.

I. Municipal Water-Works. Agricultural Engineering. Irrigation

a. General Articles

Interstate Water Rights. Caleb Mills Saville. N. E. W. W. Assoc. Dec., '27.
Public Works and State Boundaries. Clemens Herschel. N. E. W. W. Assoc. Dec., '27.

Municipal Water and Sewerage Costs in Maryland.* Abel Wolman. N. E. W. W. Assoc. Dec., '27.
An Unusual Water Works.* Willem Rudolfs. W. W. Jan., '28.
The Mokelumne River Water Supply Project for the East Bay Municipal Utility District, California.* Philip Schuyler. West. Constr. N. Jan. 10, '28.
Compensation of Executive and Technical Forces in Water Works and Other Utilities. William W. Brush. Feb., '28.
Historic Review of the Development of Sanitary Engineering in the United States During the Past One Hundred and Fifty Years. A Symposium. Discussion: George H. Fenkell, N. T. Veatch, Jr., E. R. Jones, and Leonard Greenburg. Am. Soc. C. E. Feb., '28.
Water-Works Reconstruction in Winter at Newton, N. J.* Harry G. Payrow. Eng. N. R. Feb. 2, '28.

b. Hydrology, Water Resources

Ground Water Recession in Wisconsin.* Leon A. Smith. Am. W. W. Assoc. Feb., '28.
Louisville & Nashville Meets Problem of Greater Water Supply.* F. H. Kornfeld. Ry. Eng. & Main. Feb., '28.

c. Dams and Reservoirs

Concrete Control Methods in the Construction of a Filtered Water Reservoir. W. C. Mabee. Am. W. W. Assoc. Feb., '28.
The O'Shaughnessy Dam and Reservoir.* John H. Gregory, C. B. Hoover, and C. B. Cornell. Am. Soc. C. E. Feb., '28.
Novel Crest Design for Thin Overpour Dams.* J. C. Stevens. Eng. N. R. Feb. 9, '28.
High Multiple Arch Dam at Lake Pleasant, Arizona.* Eng. Feb. 10, '28.
Building the Guernsey Irrigation and Power Dam.* F. F. Smith. Eng. N. R. Feb. 16, '28.
Uber die Sohlendichtung der Sperrmauer in Rudolfstal.* (Making Impervious the Foundation of the Wall of the Dam in Rudolfstal.) Franz Frey. Oest. Ing. Arch. Ver. Jan. 6, '28.

d. Analysis and Purification of Water

Elimination of Errors in the Ortho-Tolidin Method. F. R. McCrumb. N. E. W. W. Assoc. Dec., '27.
One Year's Operation of the Providence Filtration Plant.* Julius W. Bugbee and Elwood L. Bean. N. E. W. W. Assoc. Dec., '27.
Zeolite Process of Water Softening.* A. S. Behrman. (Paper read before Am. Chem. Soc.) W. W. Jan., '28.
Recent Developments in Water Treatment and Filtration. John R. Baylis. (Paper read before Am. Soc. Mun. Impvts.) W. W. Jan., '28.
Pasadena's Method of Handling Cross-Connections. M. S. Jones. Am. W. W. Assoc. Feb., '28.
A Cyanide Citrate Pour Plate Medium for Direct Determination of the Colon-Aerogenes Content of Water and Sewage. Am. W. W. Assoc. Feb., '28.
Colorimetiric pH Determination in a Neutral Atmosphere.* Henry F. Muer and Frank E. Hale. Am. W. W. Assoc. Feb., '28.
Cross Connections in the East Bay Cities. J. D. DeCosta. Am. W. W. Assoc. Feb., '28.
The Treatment of the Water Supply of the City of Columbus.* Charles P. Hoover. Am. Soc. C. E. Feb., '28.

e. Distribution of Water

Cross-Connections in Connecticut. Warren J. Scott. N. E. W. W. Assoc. Dec., '27.
Fighting Fires Beforehand.* C. W. Mowry. N. E. W. W. Assoc. Dec., '27.
Ice and Leakage Troubles on Water Supply Pipe-Lines.* Eng. N. R. Jan. 26, '28.
Better Pumps Cut Operating Costs.* Ry. Eng. & Main. Jan., '28.
Adapting the Distribution System of the New Rochelle Water Company to a New Source of Supply.* Am. W. W. Assoc. Feb., '28.
Water Supplies for Automatic Sprinkler Protection. Karl E. Eppich. Am. W. W. Assoc. Feb., '28.
Fire Protection. George W. Booth. Am. W. W. Assoc. Feb., '28.
The Underwriters' Association and Water Departments. Lawrence Daw. Am. W. W. Assoc. Feb., '28.
Centrifugally Cast Concrete High Pressure Pipe for Riverside. Edward R. Bowen. Am. W. W. Assoc. Feb., '28.
Irrigation in Siam. (From Administrative Report of Royal Irrig. Dept. of Siam.) Engr. Feb. 10, '28.

f. Drainage of Land

Flow of Water in Drainage Ditches.* C. E. Ramser. (Paper read before Ill. Soc. Engrs.) Eng. & Contr. Jan., '28.

J. Sewerage. Sewage and Refuse Disposal

a. Sewers and Drains

Le Probleme des Egouts en Pays plat.* (The Sewer Problem in a Flat Country.) Cl. Salmon. Assoc. Ing. Gand. Pt. 4, '27.
Fünfzig Jahre Berliner Stadtentwässerung.* (Fifty Years of Municipal Sewerage in Berlin.) F. Langbein. Ver. deu. Ing. Jan. 21, '28.

b. Sewage Disposal, Purification

Sewage Disposal Practice in England.* H. W. Streeter. (From *Bulletin* U. S. Public Health Service.) W. W. Jan., '28.

The Industrial Waste Research Problem in Southern California. R. F. Goudey. (Paper read before City & Co. Engrs. Assoc. of Los Angeles.) West. Constr. N. Jan. 10, '28.
La Grande, Oregon, Sewage Treatment Plant.* L. R. Stockman. West. Constr. N. Jan. 10, '28.
Refuse Disposal as a Factor in National Economy. F. D. Ogden. Inst. Mun. & Co. Engrs. Jan. 24, '28.
Ferric Salts as Coagulants for Activated Sludge Prior to Filtration.* F. W. Mohlman and J. R. Palmer. Eng. N. R. Jan. 26, '28.
Refuse Disposal Plants at Baltimore.* Frank K. Duncan. Eng. N. R. Jan. 26, '28.
Scarborough Township Sewerage System.* Can. Engr. Jan. 31, '28.
Cleveland's Southerly Sewage Treatment Works. Pub. W. Feb., '28.
A Garbage Disposal Report. (From Report of Int. Assoc. Street San. Officials.) Pub. W. Feb., '28.
Industrial Waste Disposal. Discussion: Edmund B. Besselievre. Am. Soc. C. E. Feb., '28.
Deep-Pit Sludge Digestion at Indianapolis Sewage-Works.* C. K. Calvert. Eng. N. R. Feb. 9, '28.
Garbage Collection and Disposal. Ralph W. Stewart. (Paper read before League of Calif. Mun.) West. Constr. N. Feb. 10, '28.
Industrial Waste Research in California. D. Donaldson. (Paper read before Co. & Mun. Engrs. Assoc., Los Angeles.) West. Constr. N. Feb. 10, '28.

K. Heat Engines

b. Steam Turbines

Versteifender Einfluss der Turbinescheiben auf die Durchbiegung des Läufers.* (Stiffening Influence of Turbine Discs on the Flexure of the Runner.) Bruno Eck. Ver. deu. Ing. Jan. 14, '28.

c. Gas and Oil Engines

The Marine Oil-Engine. C. J. Hawkins. (Paper read before Inst. Mech. Engrs.) Eng. Jan. 13, '28; Engr. Jan. 13, '28.

L. Electricity

b. Distribution and Transmission of Electricity

1. Power Plants

A Modern Electric Power Station.* J. H. Ferry. Mil. Engr. Jan.–Feb., '28.

2. Long-Distance Transmission of Energy

Chicago Regional Power Supply.* Edwin J. Fowler. West. Soc. Engrs. Dec., '27.
Operating Aspect of the Chicago Regional Power Supply.* P. B. Juhnke. West. Soc. Engrs. Dec., '27.
132 000-Volt, Single Conductor, Lead Covered Cable.* P. Torchio. A. I. E. E. Feb., '28.

d. Mechanical Uses of Electricity

1. Electric Motors

Synchronous Motors for Driving Steel Rolling Mills.* W. T. Berkshire and H. A. Winne. A. I. E. E. Feb., '28.

3. Welding

Welding Trusses for Industrial Buildings.* Andrew Vogel. (Paper read before Aff. Tech. Soc., Boston.) Eng. & Contr. Jan., '28.
The Use of Electric Welding in Structural Work.* Comwlth. Engr. Jan. 2, '28.

M. Architecture

a. Educational, Government and Scientific Buildings

Friedrich-Paulsen-Schule in Niebüll.* (Friedrich-Paulsen School in Niebüll.) Z. d. Bauver. Jan. 4, '28.
Das neue Schweizerische Bundesgerichts-Gebäude in Lausanne.* (The New Swiss Federal Courthouse in Lausanne.) E. Prince, and others. Schw. Bauz. Jan. 7, '28.

b. Business and Commercial Buildings

New Office Building Houses Engineers.* Eng. N. R. Feb. 16, '28.

c. Residences, Hotels

Ein Freiluft- und Lichtzimmer in Jeder Wohnung.—Der Siedlungs- und der Schulbau.* (An Open Air and Light Room in Each House. House and School Construction.) Dosquet. Gesund. Ing. Jan. 7, '28.

e. Hospitals and Asylums

Das Städtische Säuglings- und Mütterheim Neukölln.* (The Neukölln Municipal Infant and Maternal Home.) Arnold Orgler. Tech. Gemein. Dec. 20, '27.
Das Allgemeine Krankenhaus Hamburg-Barmbeck.* (The Hamburg-Barmbeck General Hospital.) F. Ruppel. Tech. Gemein. Serial beginning Dec. 20, '27.

O. Administration. Legislation. Economics. Statistics

a. General Legislation

Water-Power Appraisals. Discussion: Joel D. Justin, Dana M. Wood, and Franklin H Davis. Am. Soc. C. E. Feb., '28.

b. Economic Questions of a General Character, Valuations, etc.

General Contract System Versus Segregated Contracts. Ward P. Christie. Am. Soc. C. E. Feb., '28.

Contracting Business Hazards and Reforms Reviewed. (From Comm. Reports read before Assoc. Gen'l Contrs.) Eng. N. R. Feb. 2, '28.

Pre-Qualification of Bidders on Governmental Work. L. I. Hewes. (From paper read before Assoc. Gen'l Contrs.) West. Constr. N. Feb. 10, '28.

d. Administrative and Financial Management of Means of Communication

5. Railroads and Street Railways

Practical Methods in Cost Studies. Andrew Sangster. Ry. Age Feb. 4, '28.

Q. Surveying and Geodesy

Boundary Surveys. Discussion: R. H. Randall and W. H. Halsey. Am. Soc. C. E. Feb., '28.

Improved Methods Used in Surveys for Extending Piedmont & Northern Railway.* Eng. N. R. Feb. 23, '28.

R. Landscape Engineering

Some Further Notes on Steps. Frederick Law Olmstead. Land. Arch. Jan., '28.

Street Trees on Private Property.* Frederick N. Evans. Land. Arch. Jan., '28.

T. Oil and Oil Engineering

Oil Field Problems and Practices in Road Building.* A. H. Riney. Eng. N. R. Jan. 26, '28.

Employment Service

The Engineering Societies Employment Service is under the joint management of the National Societies of Civil, Mining, Mechanical, and Electrical Engineers. A Chicago office is maintained in co-operation with the Western Society of Engineers, and a San Francisco office, in co-operation with the Engineers' Club of San Francisco and the California Section of the American Chemical Society. The Service is available only to the several memberships and is maintained by contributions from the Societies and their individual members who are directly benefited.

Offices.—Eastern Office, 31 West 39th Street, New York, N. Y., Walter V. Brown, Manager; Chicago Office, 53 West Jackson Boulevard, Room 1736, Chicago, Ill., A. Krauser, Manager; and San Francisco Office, 57 Post Street, Room 715, San Francisco, Calif., Newton D. Cook, Manager.

Men Available.—Under this heading, brief announcements will be published without charge. These announcements will not be repeated, except on request received after an interval of one month. Names and records will remain in the active files of the Service for a period of three months, and are renewable on request. Notices for *Proceedings* should be addressed to Employment Service, 31 West 39th Street, New York, N. Y., and should be received prior to the first of the month.

Opportunities.—A Bulletin of engineering positions available is published weekly and may be obtained by members of the Societies concerned at a subscription rate of $3 per quarter, or $10 per annum, payable in advance. Positions which are not filled promptly as a result of publication in the Bulletin, may be announced herein.

Voluntary Contributions.—Members obtaining positions through the medium of this Service are invited to co-operate with the Societies in the financing of the work by nominal contributions made within thirty days after placement, on the basis of 1½% of yearly salary; temporary positions (of one month or less), 3% of total salary received. The income contributed by the members, together with the finances appropriated by the four Societies named, will be sufficient, it is hoped, not only to maintain but to increase and extend the Service.

Replies to Announcements.—Replies to announcements published herein, or in the Bulletin, should be addressed to the key number indicated in each case, with a two-cent stamp attached for re-forwarding, and forwarded to the Employment Service at the address given. Replies received by the Service after the positions to which they refer have been filled, will not be forwarded.

POSITION AVAILABLE

NEW BUSINESS REPRESENTATIVE on industrial report and appraisal work. Prefer graduate engineer, age 35–45. Must have practical appraisal and selling experience. Apply only by letter. Salary, more than $5 000 per year. Location, New York City. X–4349–C–S.

MEN AVAILABLE

MUNICIPAL ENGINEER. Assoc. M. Am. Soc. C. E.; age 41; married. Experienced, general town problems, street construction, pavements, sewers, disposal plants, tax maps, and traffic problems. Location, immaterial. A–4654.

CONSTRUCTION ENGINEER, Assoc. M. Am. Soc. C. E.; age 49; married. Twenty-five years' experience, railway, mines, highways. Last 8 years, highways, earth, macadam, concrete, gravel, bridges, steel, and concrete. Over 3 000 000 cu. yd. excavation. Responsible charge of over $2 500 000 highway construction. Successful handler of labor. Location, South or Southwest. A–4814–1670.

CIVIL ENGINEER, Assoc. M. Am. Soc. C. E.; technical graduate; age 40; married. Four years', manufacturing business, salesman and assistant buyer; 5 years, general constructing, steel plant; 1 year, bridge inspector, railroad; one year, district engineer's office, railroad; 9 years, assistant engineer, valuation department, railroad. Location preferred, New York or vicinity. B–465.

CONSTRUCTION ENGINEER, Assoc. M. Am. Soc. C. E., Michigan State civil engineering graduate; age 37. Four years, production and plant engineering; 11 years heavy construction, hydro-electric, industrial, and New York subways. Just completed, as resident engineer, hydro-development, dam, penstock, power house, and transmission line. Desires position with good company. B–4052.

STRUCTURAL ENGINEER, M. Am. Soc. C. E., graduate in civil engineering. Twenty years' experience on construction and valuation of industrial and utility properties. Now employed but desires change to better conditions, with utility or contractor. B–4238.

EXECUTIVE ENGINEER, M. Am. Soc. C. E.; technical graduate; age 54; married. Thirty years' general experience. Good executive. Energetic, diplomatic, and forceful. Investigations, estimates, reports. Consultant for organization and management of construction and development operations for banking and investment corporations. Highest references. Location, East or South. B–5666.

ENGINEER SALESMAN, Assoc. M. Am. Soc. C. E.; graduate civil engineer; age 34; single; with eight years' experience in construction field in various capacities, including purchasing, organization and management, desires sales or promotion position with company manufacturing construction materials or equipment. Location, preferably Atlantic or Pacific Coast. B–6886.

ENGINEER, Assoc. M. Am. Soc. C. E., graduate (1910); age 40; married. Ten years, railroad construction and maintenance as resident and division engineer for Eastern railroads. During past two years engaged as contractor's engineer on water-front construction, piers, wharves, also with New York consulting engineers on municipal work, railroad, and street grade crossing eliminations. Available at once. Location preferred, New Jersey. B–7307.

CIVIL ENGINEER OR SUPERINTENDENT OF CONSTRUCTION, Assoc. M. Am. Soc. C. E.; married. Twenty years' experience in Latin-America, wishes position in any engineering capacity in foreign parts. Can furnish a complete set of high grade instruments for field and office. Will take work on cost plus basis. B–7494.

CONSTRUCTION ENGINEER AND SUPERINTENDENT, Assoc. M. Am. Soc. C. E.; Stevens graduate; age 36; married. Twelve years in responsible capacity on subway work, steam super-power station, municipal sewage disposal system, structural steel erection, apartment house construction, soliciting, estimating, and closing new business. Location, Metropolitan District; available immediately. B–7794.

HIGHWAY ENGINEER, Assoc. M. Am. Soc. C. E.; age 38. Ten years' responsible charge of reconnaissance, locations, and construction of various types of highways, including reports, investigations, estimates, designs, and plans. Also, 7 years additional work in location, construction, and valuation of railroads, drainage, stadia topography, land lines, and plant construction; now available. Location not important. B–7839.

CIVIL ENGINEER, Jun. Am. Soc. C. E.; graduate. Five years' varied experience, structural and architectural detailing, estimating, and design. Desires position with structural engineer, architect, or contracting firm. Available two weeks after notice. B–8213.

NEW YORK AGENCY, on a commission basis, for building products desired by Civil Engineer, Assoc. M. Am. Soc. C. E., who has had long experience with prominent engineering, architectural, and manufacturing firms. Well known to architects and builders and experienced in promoting and first introduction of new products. B–9276.

RESIDENT ENGINEER OR DRAFTSMAN, Assoc. M. Am. Soc. C. E.; age 29; married. Engineer experienced in railroad construction, transmission line surveys, design and construction, highway location, mine surveys and mapping. Neat and rapid draftsman, rapid and accurate field engineer. Can produce results. Location preferred, Virginia, West Virginia, Kentucky, Tennessee, North Carolina, Pennsylvania. B–9582.

DESIGNING CIVIL ENGINEER, Assoc. Am. Soc. C. E.; age 41. Construction and designing experience since 1912, mostly on railroads and buildings. Executive ability. Willing worker and able to get results. Advanced engineering degree and foreign travel and study. Speaks French, German, and Dutch. Available immediately and will go anywhere. Salary about $400 per month. B–9873.

CONSTRUCTION OR SALES ENGINEER, Assoc. M. Am. Soc. C. E.; graduate Civil Engineer, Licensed Professional Engineer, and Land Surveyor; age 33; married. Experienced in highway engineering and promotional work. Can take complete charge of paving program from preliminary estimate and specifications to completion. Location, Metropolitan Area. C–1688.

RESIDENT ENGINEER, Assoc. M. Am. Soc. C. E., civil engineer graduate; age 33; single. Experienced in highway design, estimates, reports; preliminary and construction surveys; bridge and paving construction; can take charge of large highway office of field force. Location, prefer Middle West. C–2023–1004.

CIVIL AND MINING ENGINEER, Jun. Am. Soc. C. E., graduate civil engineer, 1925; age 26; single. One year, property line, sub-division layout. One year, coal, clay mining, mapping, topographical surveying, charge drilling for coal, clay, triangulation, copper exploration, estimates. Six months, division engineer, steam shovel mining, sampling, estimating. Available April 1. South American experience. Speaks Spanish. C–2183.

FOREMAN, Jun. Am. Soc. C. E.; age 27; single. Engineer with five years' construction and preliminary survey experience on dams, railroads, and highways, desires position as foreman on construction. Hydro-electric work preferred. Location, immaterial. C–2772.

CIVIL ENGINEER, Assoc. M. Am. Soc. C. E.; age 37; married. Field and office experience on factory building construction as surveyor, gang-boss, engineer, designer, and estimator. Experience on design and construction of power and lighting switchboards and panelboards. Three years, instructor in engineering in college. Location, anywhere. C–3237.

RESIDENT ENGINEER, Assoc. M. Am. Soc. C. E., civil engineer graduate, University of California; age 38; single. Three years, resident engineer, charge of pumping plant and power plant construction, railroad location and construction, reinforced concrete bridge construction, U. S. Army Engineer Corps. C–3387.

CONSTRUCTION ENGINEER OR ESTIMATOR, Assoc. M. Am. Soc. C. E.; age 31; married. Thirteen years' experience in design and construction of industrial buildings. Familiar with all phases of construction practise in both field and office. Eight years in responsible charge of large operations. Desires executive position with contractor or consulting engineer. Eastern or Southern States preferred. C–3457.

DESIGNING DRAFTSMAN OR CONSTRUCTION ENGINEER, Jun. Am. Soc. C. E., graduate of the University of Illinois; age 23; married. Specialized in water power and hydraulics. Three months' experience in dam construction. One year, design and construction of paved highways. Location, no objections. C–3600.

CONSULTING ENGINEER OR ASSISTANT TO CONSULTING ENGINEER, M. Am. Soc. C. E. Twenty-three years' experience in charge of all kinds of railroad engineering projects; investigations, reports, litigations, valuations, locations, economics, rate cases, design. Many years' experience on railroad and marine terminals. Speaks German, French, and English fluently. C–3609.

MANAGER OR CHIEF ENGINEER, M. Am. Soc. C. E. Capable organizer and recognized authority on valuation work. Broad background in building construction. Will consider offer from first-class engineering firm or general contractor. New York City preferred. C–3936.

DESIGNER, Assoc. M. Am. Soc. C. E., graduate civil engineer (Norwegian); age 32; married. Eight years' experience; 5 years in United States as draftsman, designer, and checker, reinforced concrete and structural steel, for sewage disposal plants, hydro-electric plants, industrial mills and plants, highway bridges. Location preferred, New York or East. C–3984.

CIVIL ENGINEER, M. Am. Soc. C. E.; 24 years' experience in general railroad construction, concrete structures, heavy bridge construction, design of concrete layouts, centering, forms, etc. Experienced in estimating as well as the direct supervision of large concrete structures. Well acquainted in this field and an excellent following. Available at once. C–4072.

ENGINEER, Assoc. M. Am. Soc. C. E.; age 33; married. Experienced, selling engineering equipment, construction, and field work. Employed as follows: Sales work for large Southern firm; assistant engineer on highway construction; engineer for contractor reinforced concrete, estimates, office and field work, etc.; rock tunnel construction and water-proofing. Will locate anywhere, but prefer Southern States. Available on short notice. C–4139.

PART TIME WORK: Civil Engineering Student with two and one-half years of practical experience in surveying, drafting (topographical and architectural), construction, inspection, design, estimating and computations, desires part-time work, afternoons (except Tuesday and Wednesday), evenings, Saturdays, or Sundays; or full-time night work in any of the above, or other, fields. C–4158.

CIVIL ENGINEER, age 27; with five years' field and office experience in marine, dock building, railroad, oil refinery, and transmission-line construction, desires position in New York or Los Angeles districts. Has been construction superintendent, engineer, and transitman, with some estimating and design work. Has been in Panama, Europe, and Northern Africa. C–4165.

STRUCTURAL ENGINEER, Jun. Am. Soc. C. E.; age 26. Eight years' experience with fabricators on large projects, desires position as checker, estimator, designer, or assistant engineer with large steel fabricator or engineering firm; best of references. Available at once. No preference regarding location. C–4179.

STRUCTURAL ENGINEER, Assoc. M. Am. Soc. C. E., graduate civil engineer; American citizen; age 33. Eleven years' experience in detailing, design, and erection of steel mill, office buildings, and bridges; 8 years, responsible charge, design; accustomed to deal with architects and owners, wishes to locate in or near Philadelphia. Desires permanent, responsible position. Good personality, executive ability. C–4186.

CIVIL ENGINEER, Jun. Am. Soc. C. E.; age 26; single. Labor foreman, steel foreman, assistant engineer doing layout and office work; inspector and resident engineer, underground tunnel work. Field engineer, doing city planning and layout. Location, anywhere. C–4193–1664.

GRADUATE ENGINEER, Jun. Am. Soc. C. E.; degrees in civil and electrical engineering; graduate study in hydraulics at State University of Iowa; age 25; single. Experience in surveying, drafting and testing electrical apparatus. Desires position as instructor or assistant professor of civil or electrical engineering. Location, anywhere; West or Southwest preferred. C–4234.

Membership

(From February 1 to March 6, 1928)

Additions

Members		Date of Membership.
ABERNETHY, Peter Link. 1335 Thirteenth Ave., Hickory, N. C.	Jun.	Oct. 10, 1927
ANDERSON, Andrew Matthew. 29 Gifford Ave., Poughkeepsie, N. Y.	Jun.	Oct. 10, 1927
ANTES, Donald Edward. City Engr., City Hall (Res., West Lincoln Highway), Coatesville, Pa	Jun.	Dec. 5, 1927
BAGNALL, Cyril Baskerville. 1034 South Catalina St., Los Angeles, Calif.	Jun.	Oct. 10, 1927
BARNES, George Eric. Cons. Engr.; Associate Prof., Civ. Eng., Univ. of Florida, Gainesville, Fla	Jun. Assoc. M.	Oct. 15, 1923 Mar. 5, 1928
BLANK, Charles Edward. University Club, Bethlehem, Pa	Jun.	Dec. 5, 1927
BLUMBERG, Oscar Charles. Draftsman, Eng. Dept., California Water Service Co., Hunter-Dulin Bldg., San Francisco (Res., 1558 Beverly Pl., Berkeley), Calif	Jun.	Jan. 16, 1928
BONNELL, Ralph Arnold, Sr. Engr. of Constr., James O. Heyworth, Inc., 606 South Michigan Ave., Chicago, Ill	M.	Jan. 16, 1928
BOOSS, George Frederick Charles, Jr. Draftsman, The Texas Co., 214 West 92d St., New York, N. Y	Jun.	Nov. 14, 1927
BOOTON, Richard Crittenden. Engr., Jagoe Constr. Co. (Res., 4057 Travis St.), Dallas, Tex	Assoc. M.	Jan. 16, 1928
BOWEN, Clare Merrifield. Eleele, Kauai, Hawaii	Assoc. M.	Nov. 14, 1927
BRICE, Norman Root. Draftsman and Designer, Wabash R. R., Care, Chf. Engr.'s Office, Wabash Ry., 1765 Railway Exchange Bldg., St. Louis, Mo	Jun.	Nov. 14, 1927
BURNUM, Hubbard Denson. Div. Engr., 1st Div., State Highway Dept., Box 71, Decatur, Ala	Assoc. M.	Aug. 29, 1927
CALDWELL, William Metz. 5016 Bliss St., Woodside, N. Y	Jun.	Dec. 5, 1927
CHEWNING, Charlie Clinton. Res. Engr., State Highway Dept., Walterboro, S. C	Jun.	Jan. 16, 1928
COHEN, Paul Arthur. Draftsman, Am. Bridge Co., Ambridge, Pa.	Jun.	Dec. 5, 1927
COLLINS, Merton Clyde. Structural and Ventilation Engr., Oakland-Alameda Estuary Subway, Oakland, Calif	Jun. Assoc. M. M.	Sept. 3, 1913 June 18, 1918 Jan. 16, 1928
CORTELYOU, Herman Polhemus. Engr. of Constr., City Engr.'s Office (Res., 1755 West 39th St.), Los Angeles, Calif	Assoc. M. M.	Mar. 15, 1926 Jan. 16, 1928
COYLE, George Love. Engr., W. F. Allen & Co. (Res., 122 Buckhannon Ave.), Clarksburg, W. Va	M.	Jan. 16, 1928
DAWSON, John Stanley. Box 18, Tucson, Ariz	Assoc. M. M.	June 1, 1920 Jan. 16, 1928
DIRLAM, Clyde Nixon. Structural Engr., City Bldg. Dept. (Res., 3912 Marathon St.), Los Angeles, Calif	Assoc. M.	Dec. 5, 1927
DURANT, Nicholas John. Asst. Bridge Engr., Indian States Rys., Office of Bridge Engr., N. W. Ry., Moghalpura, Lahore, India	Assoc. M.	Nov. 14, 1927
ENGLISH, John Greer. Constr. Engr., Stange Const. Co., 1600 Arch St., Philadelphia, Pa. (Res., 92 Tiona Ave., Belleville, N. J.)	Assoc. M.	Jan. 16, 1928
EPSTEIN, Alexander. Asst. Res. Engr., State Highway Dept., Walterboro, S. C	Jun.	Jan. 16, 1928
ERSKINE, Frank Graves. Draftsman, City Eng. Dept. (Res., 800 Gillespie St.), Jackson, Mich	Jun.	Jan. 16, 1928
FERRER, Manuel Rivera. Engr., Box 710, San Juan, Porto Rico.	Assoc. M.	Jan. 16, 1928
FOSTER, Alexander, Jr. Chf. Engr. and Pres., West Jersey Sand & Supply Corporation (Res., 6136 Oxford St.), Philadelphia, Pa.	M.	Jan. 16, 1928
FREITAS VALLE FILHO, José de. 34 Domingos de Moraes, Sao Paulo, Brazil	Jun.	Nov. 14, 1927
FROGGATT, Wilfrid Armour. 781 Ashbury St., San Francisco, Calif.	Jun.	Jan. 16, 1928
GANS, Roy Carl. Chf. Engr., Dept. of Streets and Sewers (Res., 3662 Wilmington Ave.), St. Louis, Mo	M.	Aug. 29, 1927
GREEN, Charles Henry. Draftsman, Phœnix Bridge Co., 124 Third Ave., Phœnixville, Pa	Jun.	Oct. 10, 1927
GRIFFITH, Lincoln Edward. Tracer and Detailer, Dept. of Public Works, Bureau of Eng. (Res., 4821 Lake Park Ave.), Chicago, Ill.	Jun.	Oct. 10, 1927
GUNDERSEN, August. Pres., A/S Höyer-Ellefsen, Box 39, Oslo, Norway	Assoc. M. M.	Oct. 2, 1907 Jan. 16, 1928
HARRIS, Robert Olin. 701 West 180th St., Apartment 55, New York, N. Y	Jun.	Oct. 10, 1927

MEMBERS—(*Continued*)

		Date of Membership.
JAKKULA, Arne Arthur. Univ. of Minnesota, Coll. of Eng., Minneapolis, Minn.	Jun.	Jan. 16, 1928
JERNIGAN, Otis McCrory. Insp., Ford & MacCrea (Res., 403 Ringo St.), Little Rock, Ark.	Jun.	Jan. 16, 1928
KARP, Edmund Isidore. 25 Cedar St., Babylon, N. Y.	Jun.	Oct. 10, 1927
KERCHER, Henry. Asst. Engr., The Cleveland Union Terminals Co. (Res., 3331 Glencairn Rd., Shaker Heights), Cleveland, Ohio	Assoc. M. M.	April 18, 1916 Jan. 16, 1928
KING, Harry Lindley. Junior Highway Engr., Dept. of Public Works and Bldgs. (Res., Y. M. C. A.), Springfield, Ill.	Jun.	Jan. 16, 1928
KLOTZ, Russell Louis. Singac, N. J.	Assoc. M.	Jan. 16, 1928
KNAPPEN, Theodore Temple. Div. Engr., Fred H. Tibbetts, 1320 Alaska Commercial Bldg., San Francisco, Calif.	Jun.	Jan. 16, 1928
KREUTZER, George Charles. Director of Reclamation Economics, U. S. Bureau of Reclamation (Res., 1746 K St., N. W.), Washington, D. C.	M.	Jan. 16, 1928
LARSON, Arthur George. Office Asst. and Draftsman, Univ. Endowment Lands Subdivision (Res., 2158 First Ave., West), Vancouver, B. C., Canada.	Jun.	Nov. 14, 1927
LENHARDTSON, Emilio. Sectional Chf. Engr., Argentine States Ry., Rio Bamba 1121, Buenos Aires, Argentine Republic.	Assoc. M.	Aug. 29, 1927
LIST, Albert. Asst. Civ. Engr., State of New Jersey, Board of Commerce and Nav., 18 Summit St., East Orange, N. J.	Jun.	Jan. 16, 1928
MacDUFFEE, Karl Merriel. 304 East 50th St., Seattle, Wash.	Assoc. M.	Jan. 16, 1928
McCARTHY, Charles Joseph. Eng. Executive, Chance Vought Corporation, Borden and Review Aves., Long Island City, N. Y.	Jun. M.	July 6, 1920 Jan. 16, 1928
McINTYRE, Clifford Thomas. City Engr.'s Office (Res., 248 Tennyson Ave.), Highland Park, Mich.	Assoc. M. M.	Aug. 28, 1922 Jan. 16, 1928
MAGNER, Nelson Wendell. Chf. of Party, Highway Location, R. W. Hebard & Co., Inc. & Rene Keilhauer, Santa Ana, Salvador	Jun.	Jan. 16, 1928
MARTEL, Romeo Raoul. Associate Prof., Civ. Eng., California Inst. of Technology, Pasadena, Calif.	Assoc. M. M.	June 19, 1922 Jan. 16, 1928
MARTENS, LeRoy Peter. Asst. to Foreman, U. S. Gypsum Co., 300 West Adams St. (Res., 1441 Hollywood Ave.), Chicago, Ill.	Jun.	Nov. 14, 1927
MARTIN, Henry Kautz. Instrumentman, Chesapeake & Hocking Ry., Box 441, Portsmouth, Ohio.	Jun.	Dec. 5, 1927
MENOHER, Wade Lamonte. Draftsman, Kansas City Structural Steel Co. (Res., 1634 South 21st St.), Kansas City, Mo.	Jun.	Jan. 16, 1928
MERCHANT, Lawrence Charles. Route 1, Biltmore, N. C.	Jun.	Nov. 14, 1927
MILLER, William Henry. Insp., State Highway Dept., Box 281, Darien, Ga.	Jun.	Nov. 14, 1927
MORRISON, Harry. 316 Ocean View Ave., Brighton Beach, N. Y.	Jun.	April 18, 1927
NEILL, Clayton Hewley. With Loveland Engrs., Inc., 1010 Bank of Italy Bldg., San Francisco, Calif.	Jun.	Dec. 5, 1927
O'CONNOR, John Brown. 479 West Palmer Ave., Detroit, Mich.	Jun.	Oct. 10, 1927
PARSONS, Gerald Ernest. Duck, W. Va.	Jun.	Oct. 10, 1927
PAULET, Emile George. Draftsman, State Highway Comm., Box 1277, Baton Rouge, La.	Jun.	Jan. 16, 1928
PIERCE, John Franklin. City Mgr., Box 27, Springdale, Pa.	Assoc. M.	Nov. 14, 1927
RATH, Edwin Roscoe. Mgr., Rys. Dept. Elastite Div., The Philip Carey Co., Lockland, Cincinnati (Res., 645 Glenway Ave., Wyoming), Ohio.	Assoc. M.	Jan. 16, 1928
RICHARDS, Leon Kenneth. Instrumentman, State Highway Comm., Atlantic (Res., 400 West St., Shenandoah), Iowa.	Jun.	Nov. 14, 1927
ROSS, Frank Arthur. Wheeler, Ore.	Jun.	Jan. 16, 1928
SANCHEZ, Milciades. Medellin, Colombia.	Jun.	Dec. 5, 1927
SCHOFER, August. Junior Highway Engr., Bureau of Public Roads, 235 Eighth St., N. E., Washington, D. C.	Jun.	Jan. 16, 1928
SEGURA, Valeriano. Div. Engr., Bureau of Public Works, Manila, Philippine Islands.	Jun. Assoc. M. M.	Oct. 1, 1913 May 15, 1917 Dec. 5, 1927
SHENAMAN, Irvin Shaffer. Asst. Engr., Dept. of City Transit, 2952 North Taney St., Philadelphia, Pa.	Assoc. M.	Jan. 16, 1928
SLAVIN, Harry Williams. Civ. Engr. with Los Angeles County Surv., 702 Hall of Records, Los Angeles, Calif.	Assoc. M.	Dec. 5, 1927
SMITH, Richard Wilson. 1422 Thirty-seventh Ave., Seattle, Wash.	Jun.	Oct. 10, 1927
SMITH, Waldo Edward. Instr., Univ. of Illinois, 210 Eng. Hall, Univ. of Illinois, Urbana, Ill.	Jun.	Nov. 14, 1927
SNYDER, James Sinclair. 168-44 Ninety-second Rd., Jamaica, N. Y.	Jun.	Dec. 5, 1927
SPAFFORD, Hildreth Ancel. San. Engr., Logan County Health Dept., Box 997, Logan, W. Va.	Jun.	Oct. 10, 1927
STEM, Albert Franklin. 356 Heberton Ave., Port Richmond, N. Y.	Jun.	Jan. 16, 1928
THOMAS, Weston Gage. With Copper & Brass Research Assoc., 25 Broadway (Res., 122 East 30th St.), New York, N. Y.	Jun.	Oct. 10, 1927

MEMBERS—(*Continued*)		Date of Membership.
THOMPSON, Walter Edwin. Junior Engr., New York State Transit Comm., 270 Madison Ave., New York (Res., 410 Ninety-fourth St., Woodhaven), N. Y.	Jun.	Jan. 16, 1928
TOTH, Alexander Stephen. Structural Draftsman, Picatinny Arsenal, War Dept., U. S. Govt., 12 East Blackwell St., Dover, N. J.	Jun.	Jan. 16, 1928
TYNAN, John William. Arlington, Vt.	Jun.	Oct. 10, 1927
VINCENT, George Sylvester. Asst. Bridge Engr., State Highway Dept., Little Rock, Ark.	Jun. Assoc. M.	May 8, 1922 Jan. 16, 1928
WHILDEN, Carleton Nettles. Care, The McClelland Co., Wilson Bldg., Charlotte, N. C.	Jun.	Nov. 14, 1927
WILKERSON, Robert Lathair. Box 271, Prattville, Ala.	Jun.	Nov. 14, 1927
YOUNG, Brian Oliver. Engr. and Mgr., Hume Pipe Co. (Aust.) Ltd., Box 4534 G. P. O., Melbourne, Victoria, Australia	Jun.	Oct. 10, 1927

Reinstatements

MEMBERS	Date of Reinstatement.
FLICK, John Kramer	February 23, 1928

Deaths

BAYLY, Howard Paul. Elected Associate Member, April 16, 1918; died August 22, 1927.
BEAHAN, Willard. Elected Member, April 3, 1889; died February 5, 1928.
BROWNELL, Ralph Elijah. Elected Member, November 9, 1920; died January 23, 1928.
BURDEN, James. Elected Associate Member, February 5, 1902; Member, January 5, 1904; died March 1, 1928.
BURNELL, Eugene Dickinson. Elected Associate Member, June 4, 1913; Member, September 9, 1919; died February 20, 1928.
FELT, Charles Frederick Wilson. Elected Member, March 3, 1897; died February 4, 1928.
FORD, William Hayden. Elected Junior, November 5, 1895; Associate Member, June 3, 1903; Member, September 1, 1908; died February 9, 1928.
HOSMER, Guy Frederic. Elected Associate Member, November 6, 1907; died January 27, 1928.
LECKLITER, Walter Harlan. Elected Junior, October 1, 1912; Associate Member, August 31, 1915; died January 29, 1928.
MAXSON, Frank Oscar. Elected Member, May 1, 1889; died January 21, 1928.
SELANDER, John Einar. Elected Member, November 4, 1908; died March 30, 1927.
SESSIONS, John Montague. Elected Junior, December 4, 1922; died December 14, 1927.
SNYDER, Hunter Imboden. Elected Junior, November 30, 1909; Associate Member, January 7, 1913; died January 28, 1928.
THORNDIKE, Sturgis Hooper. Elected Member, January 6, 1915; died February 16, 1928.
WINGFIELD, Nisbet. Elected Member, May 1, 1895; died February 24, 1928.

Total Membership of the Society, March 6, 1928

Members	**5 425**	
Associate Members	**5 696**	
Corporate Members		**11 121**
Honorary Members		**15**
Juniors		**1 619**
Affiliates		**139**
Fellows		**7**
Total		**12 901**